The Federal Plan for Meteorological Services and Supporting Research Fiscal Year 2007

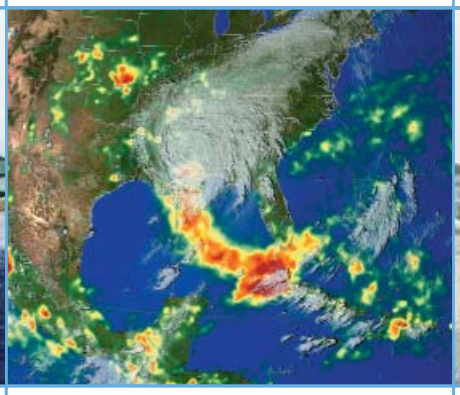
Tropical Cyclone Research

INTENSITY/STRUCTURE

TRACK

SEA STATE

SURGE



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OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY

FCM-P1-2006

U.S. DEPARTMENT OF COMMERCE/National Oceanic and Atmospheric Administration

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Pictures displayed on the cover.
Intensity/Structure: A NOAA GOES East visible image of Hurricane Rita on September 23, 2005, along with an example of a H*Wind "snapshot" product (Hurricane Rita, 1930 UTC, 23 Sep 2005). (ftp://ftp.aoml.noaa.gov/pub/hrd/hwind/2005/al18.2005/0923/1930/col02deg.png)
Track: Graphic of hurricane tracks for the record-breaking 2005 hurricane season. (NOAA)
Sea State: View of sea state from a ship's bridge offshore Newfoundland. (http://tv-antenna.com/heavy-seas/3/)
Surge: Storm surge is a rapid rise of sea level that occurs as a hurricane approaches a coastline. (http://www.ihc.fiu.edu/images/storm_surge_2.jpg)
Precipitation: This image shows rain accumulation from Hurricane Katrina for August 30, 2005, based on data from the NASA TRMM Multisatellite Precipitation Analysis shown in colors ranging from green (less than 30 mm) through red (80 mm or more). Satellite cloud data is overlaid for context. (http://svs.gsfc.nasa.gov/vis/a000000/a003200/a003239/index.html)
Social Science: Last minute evacuees flee the hurricane. Can we prevent this situation from happening? (http://news.bbc.co.uk/2/low/science/nature/474296.stm)

The Federal Plan for Meteorological Services and Supporting Research

FISCAL YEAR 2007

FEDERAL COORDINATOR
FOR
METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

8455 Colesville Road, Suite 1500
Silver Spring, MD 20910
301-427-2002

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OCTOBER 2006
WASHINGTON, D.C.

Editors: Frank Estis
Kenneth Barnett

PREFACE

Since 1965, the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) has developed a Federal Plan that articulates the provision of meteorological services and the support for meteorological and related research by agencies of the Federal government. OFCM's 2007 Federal Plan provides Congress and the Executive Branch with a comprehensive compilation of proposed programs for fiscal year (FY) 2007 and a review of agency programs in FY 2006. The Federal Plan's narratives, timelines, and schedules are current as of August 2006.

The Federal Plan consists of an Executive Summary, three sections, and Appendices. The Executive Summary, which is written as a concise, stand-alone report, provides a high-level view of the Federal resources dedicated to meteorological programs and the achievements of those programs.

This year's feature article (Section 1) reviews three projects focused on tropical cyclone (TC) research and development (R&D) to improve the Nation's tropical cyclone forecast and warning service. After briefly reviewing the three projects, the article provides more details on one of the projects, the development of an OFCM-sponsored interagency strategic TC research plan. A revolution in the accuracy and utility of weather forecasts has occurred in the past several decades. This revolution has also improved forecasts and warnings for tropical cyclones. Nevertheless, further improvements to the Nation's tropical cyclone forecast and warning service are feasible, within reach, and valuable investments for our safety, security, and economic well-being. Whether called “hurricanes” (in the North Atlantic and in the Pacific off the coasts of the Americas), “typhoons” (in the Pacific west of the dateline), or other regional appellations, these severe cyclonic storms are causing increasing amounts of destruction, death, and injury primarily because both population density and economic infrastructure in coastal regions continue to increase. Tropical cyclone forecasting has been and continues to be a challenge. However, the capability to begin gaining skill in forecasting rapid intensity changes, better predicting hurricane structure, sea state and storm surge, and precipitation is now on the horizon much like improving track was a decade or so ago due to continued improvements in observational capabilities, and recent advancements in numerical weather prediction model physics and data assimilation systems.

Section 2 of the Federal Plan summarizes the resources requested in the President's FY 2007 Budget, compared with the resources appropriated by Congress for FY 2006. Section 3 contains departmental and agency narratives on programs for providing meteorological services and supporting research and development. It also describes relevant research funded by the National Science Foundation.

Appendix A describes the OFCM's coordination, program, and planning activities. Appendix B addresses the World Meteorological Organization's World Weather Program. Appendix C lists the feature articles published in previous Federal Plans. The acronyms and abbreviations used throughout this year's Federal Plan are defined in Appendix D. The inside front cover lists the current members of the Federal and Interdepartmental Committees for Meteorological Services and Supporting Research, which provide guidance and support for OFCM activities. The inside back cover diagrams the infrastructure through which the OFCM performs its coordinating mission.

Samuel P. Williamson's Signature

Samuel P. Williamson
Federal Coordinator for Meteorological
Services and Supporting Research

THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH, FISCAL YEAR 2007

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THE FEDERAL PLAN FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

FISCAL YEAR 2007

EXECUTIVE SUMMARY

For Fiscal Year (FY) 2007, the President's budget requests over a total of $3.44 billion for meteorological services and supporting research. Of the requested total, over $3.03 billion is designated for operations and over $413.7 million for supporting research. Table ES-1 lists a breakout of the FY 2007 budget proposal.

For FY 2007, 92.7 percent of the total funds requested will go to the Departments of Commerce (DOC), Defense (DOD), and Transportation (DOT). The distribution among these three departments is DOC 59.3 percent, DOD 17.5 percent, and DOT 15.9 percent. The other Federal agencies will share the remaining 7.3 percent.

By comparison, the FY 2007 request represents an increase of 3.9 percent above the over $3.31 billion appropriated in FY 2006. Within the three major departments, DOC requests an increase of 4.2 percent; DOD an increase of 2.1 percent, and DOT an increase of 7.3 percent. The DOC increase is attributable to requests for increases by NWS, NESDIS, and NOS. The overall DOD increase is mainly the result of increases in AF and DMSP requested funding. DOT's increase is attributable to an increase in FAA's operations requests.

The budget requests for the other departments are as follows:

- Department of Agriculture (USDA) a decrease of 14.7 percent,
- Department of the Interior (DOI) no change,
- Environmental Protection Agency (EPA) no change,
- National Aeronautics and Space Administration (NASA) an increase of 2.2 percent, and
- the Nuclear Regulatory Commission (NRC) no change.

Figure ES-1 depicts each agency's proportion of the requested FY 2007 Federal budget for meteorological operations and supporting research. Each agency's portion of the requested funding for meteorological operations is shown in Figure ES-2. Of the over $3.03 billion requested for meteorological operations, DOC, DOD, and DOT account for 98.6 percent of the funds. Overall, operational costs increased by 5.6 percent. Figure ES-3 depicts each agency's portion of the proposed Federal supporting research budget. Unlike operations, DOC, DOD, and NASA account for the major share (83.5 percent) of the supporting research budget. Overall, supporting research costs decreased by 7.5 percent.

All agencies project a personnel total of 13,505 full-time equivalent (FTE) to be employed in Federal meteorological operations in FY 2007. This figure represents a decrease of 13.5 percent from the 15,613 FTE employed in FY 2006, with the largest share of the decrease attributed to a reduction in DOT/FAA personnel due to outsourcing activities.

Table ES-1. Federal Budget for Meteorological Operations and Supporting Research, FY 2007 (in thousands of dollars)

Agency	Operations	% of TOTAL	Supporting Research	% of TOTAL	TOTAL	% of TOTAL
Agriculture	$19,710	0.7	$31,395	7.6	$51,105	1.5
Commerce	1,954,209	64.5	89,787	21.7	2,043,996	59.3
Defense	514,056	17.0	89,369	21.6	603,425	17.5
Homeland Security	20,110	0.7	0	0.0	20,110	0.6
Interior	2,400	0.1	0	0.0	2,400	0.1
Transportation	518,624	17.1	27,800	6.7	546,424	15.9
EPA	0	0.0	9,000	2.2	9,000	0.3
NASA	2,463	0.1	166,400	40.2	168,863	4.9
NRC	120	0.0	0	0.0	120	0.0
TOTAL	$3,031,692	100.0*	$413,751	100.0	$3,445,443	100.0*

* Column total does not exactly equal 100 percent due to rounding for several agencies.

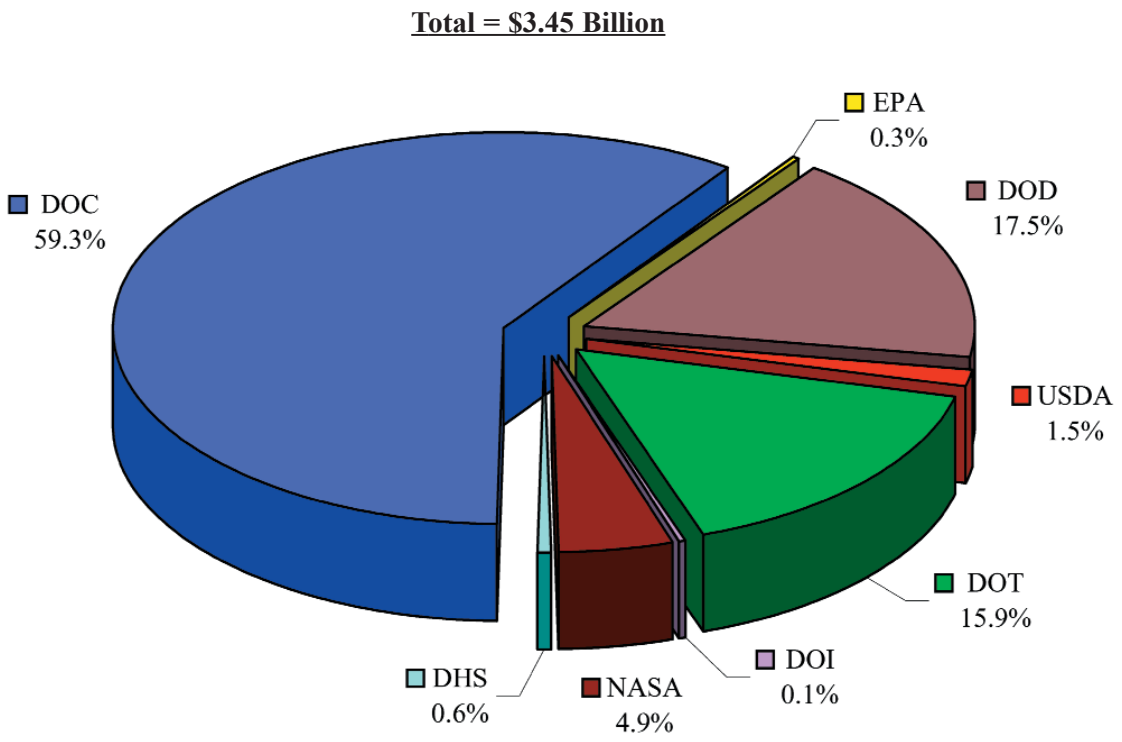


Figure ES-1. Agency Percent of Total Federal Budget for Meteorological Operations and Supporting Research, FY 2007.

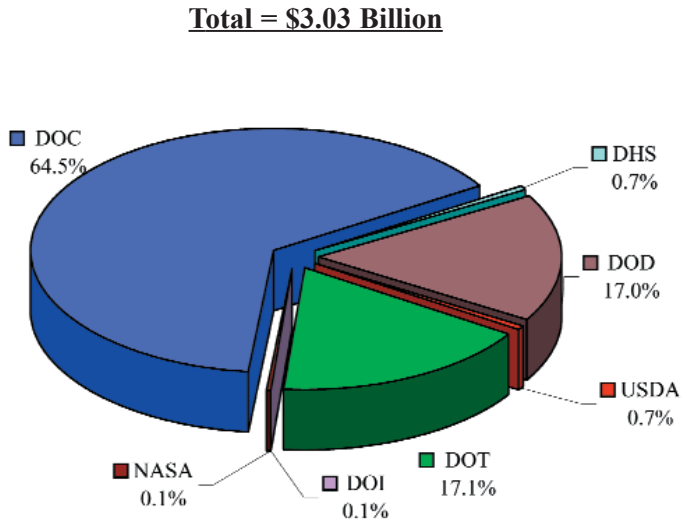


Figure ES-2. Agency Percent of Federal Budget for Meteorological Operations, FY 2007.

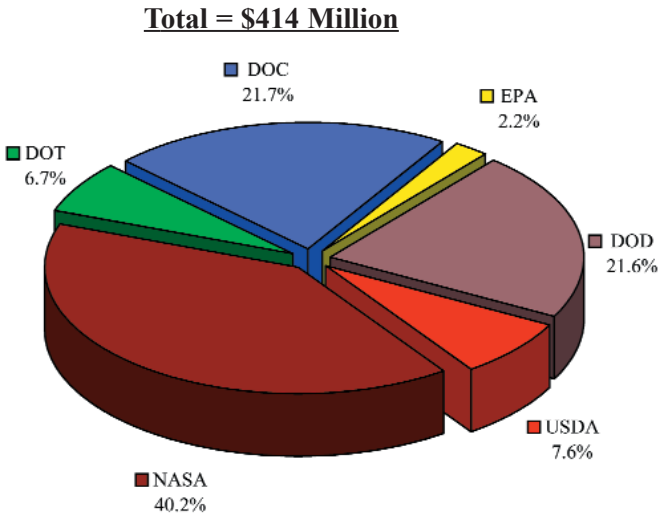


Figure ES-3. Agency Percent of Federal Budget for Supporting Research, FY 2007.

MAJOR PROGRAMS--DOC, DOD, and DOT

NEXT GENERATION WEATHER RADAR (NEXRAD)

The NEXRAD Program, begun in FY 1981, was responsible for procurement, installation, and operation of the Weather Surveillance Radar-1988 Doppler (WSR-88D). The first limited production WSR-88D system was installed at Norman, Oklahoma, in May 1990, and commissioned in February 1994. In response to a National Research Council report, three additional radars were added to the original program plan, raising the total to 158. The last system in the basic procurement schedule was installed in December 1996.

By agency, DOC/National Weather Service commissioned 120 sites, DOD (USAF) commissioned 26 sites (Continental United States (CONUS) and overseas), and DOT/FAA commissioned 12 sites. DOC/NWS has two each systems at the National Reconditioning Center and the NWS Training Center, in Kansas City, Missouri, and the Radar Operation Center, Norman, Oklahoma. DOD has two systems at Keesler AFB, Mississippi, for training.

AUTOMATED SURFACE OBSERVING SYSTEM (ASOS)

The ASOS program began in 1983 as a joint development effort between the DOC, DOD, and DOT/FAA. ASOS installation started in 1992. To date, 1009 units have been purchased, accepted, and commissioned: 313 by NWS, 572 by FAA (accepted and commissioned by the NWS), 77 by the Navy, and 47 by the Air Force. The Air Force Observing System-21st Century (OS-21) program is providing a state-of-the-art life-cycle replacement for Air Force observing equipment. OS-21 includes five different configurations: fixed, deployable, remote, manual, and upper air. Installation of 110 fixed systems, designated the FMQ-19, at Air Force bases and Army posts worldwide began in summer 2002, and is scheduled for completion in 2007. The manual version is intended for tactical operations and will continue upgrades begun under the Manual Observing System and Tactical Meteorological Observing System modification programs.

In support of operations in Kosovo, the Air Force purchased commercial off-the-shelf (COTS) remote miniature weather sensors to provide accurate real-time weather information from forward unmanned locations and has since deployed remote miniature sensors to Afghanistan and Iraq.

AUTOMATED WEATHER INFORMATION SYSTEMS (AWlS)

The DOC, DOD, and DOT require AWISs to facilitate the collection, processing, and interpretation of meteorological data. AWISs are being procured to provide an automated, high-speed, user-friendly man/machine interface to access and process large volumes of sophisticated meteorological data. AWIS supports timely production of accurate and geographically precise warnings, forecasts, and specially tailored products while including a communications capability to facilitate expeditious dissemination.

Major agency systems classified as AWISs are: NOAA's Advanced Weather Interactive Processing System (AWIPS), FAA's Weather and Radar Processor (WARP), Air Force's Joint Environmental Toolkit (JET), and the Navy's Naval Integrated Tactical Environmental Subsystem (NITES).

Advanced Weather Interactive Processing System (AWIPS)

In February 1997, the Secretary of Commerce approved the limited deployment of AWIPS at over 40 sites. On April 9, 1998, the Secretary authorized full-scale production and deployment of AWIPS, through Build 4.2, for the remaining 95 systems. Installation of these 95 systems began in September 1998 and was completed in June 1999. An Operational Test and Evaluation of the commissioning software load (Release 4.2) was successfully conducted from mid-May through June 1999. AWIPS commissioning began in January 2000, was completed in November 2000, with 139 NWS systems commissioned at 122 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), the Spaceflight Meteorology Group (SMG), and 4 National Centers for Environmental Prediction (NCEP).

The NWS successfully completed the final development phase release of AWIPS (Build 5) in early 2003, completed deployment of its first Operational Build (OB1) that summer, completed deployments of OB2 in December 2003, OB3 in August 2004, OB4 in February 2005, and OB5 in December 2005. Deployment of Operational Builds continue at about two per year. The Operational Builds deliver new functionalities and enhancements in the areas of warning product generation and warning support, hydrological product generation, data and imagery display, communications and infrastructure. Of note within the operational builds of AWIPS, is an evolution of the architecture to the Linux open source operating environment which was started in 2001, and will continue through to its planned completion in early 2007.

WARP

The FAA's WARP will greatly enhance the dissemination of aviation weather information throughout the National Airspace System (NAS). WARP will automatically create unique regional, WSR-88D-based mosaic products and send these products, along with other time-critical weather information, to controllers through the Advanced Automation System (AAS), as well as to pilots via the aeronautical data link.

JET

JET will replace several disparate

legacy weather systems with a single, integrated means of supporting both garrison and deployed operations, including a "first-in" weather forecasting capability. Combining forecasting, product-tailoring, and mission-impact capabilities in an interactive, network-centric, standards-based package; JET accesses, processes, analyzes, tailors, and integrates terrestrial and space weather information into command and control systems to guide warfighter decision-making. This effort will eliminate Air Force Weather Weapon System (AFWWS) redundancies and inefficiencies, reduce the burden on system administrators, and ultimately extend, consolidate, or replace the following systems: Operational Weather Squadron (OWS) Production System Phase II (OPS II); the New-Tactical Forecast System (N-TFS); the Joint Weather Impacts System (JWIS); and the Army's Integrated Meteorological System (IMETS) weather toolkit.

NITES

The current series of NITES (I-IV) were reengineered from the Tactical Environmental Surveillance System (TESS) and other legacy systems of the early 1990's. These NITES systems are fielded through FY 2010 and have various capabilities to ingest, process, fuse, display, and disseminate METOC information and its impact on tactical operations. In early 2000, the NITES II application software was redesigned to align with the Global Command and Control System (GCCS) Family of Systems (FoS) 4.x, provide increased flexibility, enable operating system/hardware independence, and improve user operability with a new graphical-user interface (GUI) for tactical decision aid applications. The NITES II Redesign (N2R) suite of software is integrated with both GCCS-Maritime (M) and GCC S-Joint (J) 4.x versions.

The Navy is currently reviewing the requirement to field a follow-on system, called "*NITES - Next*", to increase the capabilities for ashore, afloat and mobile METOC support to naval tactical operations and be interoperable with the other services. *NITES - Next* would have four components including: tactical applications, a forecaster's toolkit, a data services package, and the ability to collect METOC information through organic sensors for rapid environment analyses. *NITES - Next* will interface with the data providers/users using Web services and take advantage of the future DOD Global Information Grid (GIG) and Navy FORCEnet architectures. Navy is also analyzing how to efficiently and effectively leverage the Air Force's Joint Environmental Toolkit (JET) Program for meteorological and environmental impact support.

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS)

On October 3, 1994, NOAA, DOD, and the National Aeronautics and Space Administration (NASA) combined the nation's military and civilian environmental satellite programs and created an Integrated Program Office (IPO) to develop, manage, acquire, and operate the national polar-orbiting meteorological satellite system, subsequently designated the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The IPO is organizationally located within NOAA and is headed by a System Program Director responsible to the NPOESS Executive Committee. This committee, which consists of the Under Secretary of Commerce for Oceans and Atmosphere, the Under Secretary of the Air Force, and the NASA Deputy Administrator serves as a board of directors to ensure that overall program plans also meet the individual needs of the three participating agencies.

The IPO concept provides each of the participating agencies with lead responsibility for one of three primary functional areas. NOAA has overall responsibility for the converged system and is responsible to the IPO for satellite operations. NOAA is also the primary interface with the international and civil user communities. DoD is responsible to support the IPO for major systems acquisitions including launch support. NASA has a primary responsibility for facilitating the development and incorporation of new cost-effective technologies into the converged system. Although each agency provides certain key personnel in their lead role, each functional division is staffed by tri-agency work teams to maintain the integrated approach.

Pursuant to section 2433 of title 10, United States Code, Congress was notified on September 28, 2005 that NPOESS Program Acquisition Unit Cost (PAUC) would be exceeded by 15 percent. Since the fall of 2005, the fundamental management structure of the management chain at the IPO has been changed to improve the lines of communication and reporting. A Program Executive Office (PEO) organization has been added to work interagency and external activities which allows the System Program Director to focus on the acquisition process. After further cost and alternatives were analyzed, a subsequent certification notification went to Congress on January 12, 2006 indicating cost growth of greater than 25 percent. This notification begins the Nunn-McCurdy certification process, which requires the Under Secretary of Defense (USD) for Acquisition, Technology and Logistics (AT&L) certify to Congress that:

- Such acquisition program is essential to national security;
- There are no alternatives that provide equal or greater military capability at less cost;
- The new estimates of the program costs are reasonable; and
- The management structure for the program is adequate to manage and control costs.

On June 5, 2006 the Under Secretary of Commerce for Oceans and Atmosphere, the Administrator of NASA and the Under Secretary of Defense (AT&L) agreed to restructure the NPOESS program. The USD (AT&L) certifies that with respect to the restructured NPOESS program that:

- Such acquisition program is essential to the national security;
- There are no alternatives to such acquisition program which will provide equal or greater military capability at less cost;
- The new estimates of the program acquisition unit cost or procurement unit cost for such program are reasonable; and
- The management structure for such acquisition program is adequate to manage and control program acquisition unit cost or procurement unit cost.

As restructured the NPOESS includes two Engineering and Manufacturing Development (EMD) satellites, with the option in FY 2010, of exercising a renegotiated procurement option for two additional NPOESS satellites. The restructured program includes the Visible/Infrared Imager/Radiometer Suite (VIIRS); Microwave Imager/Sounder; Search and Rescue Satellite Aided Tracking (SARSAT); Cross-track Infrared Sounder (CrIS); Advanced Technology Microwave Sounder (ATMS); Advanced Data Collection System (ADCS); Cloud and Earth Radiant Energy System (CERES) [to be flown on satellite C-1 only]; Ozone Mapping and Profile Suite (OMPS) - Nadir; and the Space Environment Monitor (SEM). The Conical Scanning Microwave Imager/Sounder (CMIS) is terminated while developing a competition for a new Microwave Imager/Sounder starting with the second EMD satellite.

Funding is not available for the Aerosol Polarimetry Sensor (APS); Total Solar Irradiance Sensor (TSIS); OMPS-Limb; Earth Radiation Budget Suite (ERBS); Altimeter (Alt); Survivability Sensor (SuS); and the Full Space Environment Sensors (SESS). However, the program will plan and fund for integration of these sensors onto the NPOESS satellite buses, if the sensors are provided from outside the program.

NPOESS is a two-orbit rather than three-orbit program that uses data from the European Meteorological Operational (METOP) satellites provided by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) for the mid-morning orbit, while providing flexibility to deploy Defense Meteorological Satellite Program (DMSP) satellites depending on the health of the constellation in either early-morning or mid-morning orbits. The launch schedule for the restructured program is as follows:

- NPOESS Preparatory Project (NPP) - January 2010;
- Two EMD satellites (C-1 - January 2013 and C-2 January 2016); and
- An option in FY 2010 for block upgrade satellites (C-3--January 2018 and C-4--January 2020).

The restructured program provides for continuity of existing programs, constellation management flexibility, and the most capability for the least cost, while maintaining growth potential to achieve the original capability envisioned for NPOESS.

OTHER AGENCY PROGRAMS

For FY 2007, the Department of Agriculture (USDA) requested $51.1 million for meteorological operations and supporting research. Operationally, the USDA supports specialized weather observation networks and also conducts an active supporting research program to ensure an abundance of high-quality agricultural commodities, while minimizing the adverse effects of agriculture on the environment. Under supporting research, USDA focuses on the interactions of weather and climate with plant and animal production and water resources management.

The Department of the Interior's (DOI) FY 2006 request of $2.4 million is primarily to support the Bureau of Land Management's Remote Automatic Weather Station (RAWS) program.

The Environmental Protection Agency (EPA) budget request for FY 2007 is $9.0 million, the same amount as in FY 2006, to provide user-appropriate and scientifically credible air-quality and meteorological programs and models to support regulatory applications.

NASA's FY 2007 request is for just over a total of $168.8 million--over $2.4 million for operations and over $166.4 million for supporting research. These funding levels are composed of the estimated meteorology share of the supporting research and analysis programs as well as Earth Observing System (EOS) and Earth Probe instruments, EOS science, and the EOS Data Information System elements of the NASA Office of Earth Science budget.

The Nuclear Regulatory Commission's (NRC's) request for $120,000 in FY 2007 is for operations. The NRC will dedicate these funds to obtain and analyze meteorological data and information related to siting new nuclear power plants and safe operation of nuclear facilities, to the protection of public health and safety, and protection of the environment.

FEDERAL COORDINATION (See Appendix A for complete details.)

NATURAL DISASTER REDUCTION

INTERDEPARTMENTAL HURRICANE CONFERENCE

The OFCM annually hosts the Interdepartmental Hurricane Conference (IHC) to provide a forum for the responsible federal agencies, together

with representatives of the user communities such as emergency management, to review the nation's hurricane forecast and warning program and to make recommendations on how to improve the program. The OFCM hosted the 60th IHC in Mobile, Alabama, March 20-24, 2006. The theme of the 2006 conference was *Hurricane Season 2006: Building on the Historic 2005 Season*. The conference attendance was more than 240; for the seventh consecutive year, attendance has exceeded 200. VADM Conrad C. Lautenbacher, Jr., USN (Ret.), Under Secretary of Commerce for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration (NOAA), set the tone for the meeting during his Monday afternoon keynote address-Power of Partnerships: Prediction and Protection, noting that the only way to protect lives, property, and the economic well-being of our citizens is through partnerships. As a result, the importance of building partnerships became the central theme of the conference which the attendees took to heart. Actions resulting from the conference are: (1) publish the *2006 National Hurricane Operations Plan*; (2) through the Joint Action Group for Tropical Cyclone Research (JAG/TCR), further refine the draft strategic research plan for tropical cyclones based on the input received during the 60th IHC workshop; (3) develop a Strategic Plan for Improved Tropical Cyclone Reconnaissance Systems (ITCRS) (manned, unmanned, space-based, etc.); (4) facilitate bringing together the Web site owners from NOAA (e.g., Hurricane Research Division, National Hurricane Center), Navy, etc., to improve linkages for supporting research and development; and (5) adopt recommendations for action in a comprehensive effort to improve *getting the "right" message to the customer*. In May 2006, the 44th edition of the *National Hurricane Operations Plan (NHOP)*, which provides the basis for hurricane reconnaissance for the 2006 season and details federal agency responsibilities, operations, and procedures; products; aircraft, satellite, radar, and buoy data collection; and marine weather broadcasts, was published based on the inputs and discussions from the 60th IHC.

TROPICAL CYCLONE RESEARCH AND DEVELOPMENT PLAN

Actions from previous meetings of the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) and Interdepartmental Hurricane Conferences (IHC) called for the preparation of a tropical cyclone strategic research plan. This is being accomplished by the OFCM Joint Action Group for Tropical Cyclone Research (JAG/TCR). OFCM will publish the *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead* in fall 2006. It will then focus on development of a *Strategic Plan for Improved Tropical Cyclone Reconnaissance Systems* (manned, unmanned, space-based, etc.).

NATIONAL HURRICANE CONFERENCE

OFCM participated in the 28th Annual National Hurricane Conference (NHC) in Orlando, Florida, April 10-14, 2006. On April 11, OFCM conducted a training session in conjunction with the conference. The theme of the training session was *Warning Messages: Improving Response*. The training session focused on hurricane messages and communication, and introduced a new proposed communications model that reflects the divergent information needs of various users. Approximately 200 conference attendees participated in the training session, which validated the need to revisit the warning process. It was also emphasized that the results of social science research need to be an integral part of the hurricane forecast and warning program.

POST-STORM DATA ACQUISITION

The OFCM continued to coordinate, as required, timely post-storm data acquisition surveys in response to Presidentially declared natural disasters and other agency requirements to evaluate, for example, the impact on the coastal ecosystems. These natural disaster reduction efforts contribute to the determination of the intensity and magnitude of storms, and, in many cases, help to determine the extent of damage for use in Presidential disaster declarations. In FY 2006, post-storm surveys were conducted for Hurricane Rita and after the April 7, 2006, tornado outbreak in central Tennessee.

URBAN METEOROLOGY

NATIONAL WILDLAND FIRE WEATHER NEEDS ASSESSMENT

An important contribution to urban meteorology during the period of this report is related to the National Wildland Fire Weather Needs Assessment which is being conducted by OFCM. The formation of the Joint Action Group for National Wildland Fire Weather Needs Assessment (JAG/NWFWNA) and conduct of the assessment is responsive to ICMSSR Action Item 2005-1.1 where ICMSSR "concurred that OFCM should move forward to form a Joint Action Group (JAG) under the Committee for Environmental Services, Operations, and Research Needs (CESORN), to review the needs and requirements for wildland fire weather information, to include identifying organizational responsibilities and addressing the following issues: data collection, fire weather research, weather forecast services, data assimilation, air quality, information dissemination, education and outreach, and user response." An abundance of accumulated biomass in

forests and rangelands, persistent drought conditions, and encroaching urbanization are contributing to larger, more costly wildland fires; and to effectively manage and suppress wildland fires, fire managers need timely, accurate, and detailed fire weather and climate information. An important benchmark is the June 2005 Western Governors' Association (WGA) meeting where they approved Policy Resolution 05-04: National Wildland Fire Weather Program. Within the policy, the WGA urged NOAA to have the OFCM complete a National Needs Assessment Report of federal, state, and local fire managers' needs for weather information in their wildfire and prescribed fire decision making processes and a framework to meet those needs by the National Weather Service and Predictive Services. The JAG/NWFWNA was established in December 2005 and has moved forward to conduct the assessment.

ATMOSPHERIC TRANSPORT AND DIFFUSION RESEARCH AND DEVELOPMENT

OFCM developed an atmospheric transport and diffusion (ATD) implementation strategy for the recommendations for which OFCM has primary responsibility in the *Federal Research Needs and Priorities for Atmospheric Transport and Diffusion Modeling* (September 2004) report. In accordance with this, OFCM formed a Joint Action Group for the Joint Urban Test Beds (JAG/JUTB) under the Working Group for Urban Meteorology (WG/UM); and this joint action group is continuing work to develop an operational concept document for multi-functional joint urban test beds to provide services and data to model developers, test and evaluation personnel, and users.

CLIMATE

OFCM supports the U.S. Climate Change Science Program (CCSP). OFCM arranged for Dr. James R. Mahoney, former Director of the CCSP, to brief the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) so that member agencies can stay abreast of the program and coordinate priorities for atmospheric requirements through OFCM for inclusion in CCSP. Further, OFCM used its infrastructure to reach out and invite many government, private, and academic individuals to attend the November 14-16, 2005, *CCSP Climate Science in Support of Decision Making* workshop, and this resulted in substantially increased attendance of the workshop; and OFCM provided interagency funding support for an evening poster session of the workshop. OFCM also prepared results of a Climate Services Survey to identify new climate products and services that have been developed and implemented since the Board on Atmospheric Sciences and Climate defined "climate services" in 2001 as "the timely production and delivery of useful climate data, information, and knowledge to decision makers."

OPERATIONAL PROCESSING

OFCM's activities regarding Operational Processing Centers (OPC) continue opportunities to improve processing and backup capabilities of NOAA's National Centers for Environmental Prediction and Office of Satellite Data Processing and Distribution, the Air Force Weather Agency, and the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center and Naval Oceanographic Office. Efforts continue to improve backup support and capabilities and to coordinate preparation for the implementation of the Weather Research and Forecasting (WRF) modeling system, in accordance with the *National Concept of Operations Framework for the Operational Processing Centers*, which is contained in an April 1, 2004, memorandum of agreement signed by the directors of the OPC's. Of particular significance during this period is the establishment of a National Operational Processing Centers (NOPC) Program Council within the OFCM coordinating infrastructure, to help achieve national priorities by focusing agency efforts and leverage resources to gain the maximum return.

ANNUAL FEDERAL PLAN

In October 2005, the OFCM issued *The Federal Plan for Meteorological Services and Supporting Research-Fiscal Year 2006*. The Federal Plan is congressionally mandated and is a one-of-a-kind document which articulates the meteorological services provided and supporting research conducted by agencies of the federal government. The Federal Plan helps to reduce overlap and duplication among the agencies. It is a comprehensive publication that documents proposed programs for FY 2006 and reviews agency programs in FY 2005.

WEATHER INFORMATION FOR SURFACE TRANSPORTATION

Since 1998, OFCM has made weather services and research and development (R&D) activities supporting the surface transportation community a priority for the federal meteorological community. In December 2002, OFCM published the comprehensive report, *Weather Information for Surface Transportation-National Needs Assessment Report*, which provides the first ever compilation and analysis of weather support needs across six surface transportation sectors (roadway, railway, transit, marine transportation, pipeline systems, and airport ground operations). In August 2004, OFCM established the Working Group for Weather Information for Surface Transportation (WG/WIST) to develop both a WIST R&D Plan and a WIST Implementation Plan. In August 2006, OFCM published the report, *Weather Information for Surface*

Transportation-Update on Weather Impacts and WIST Results. This update focuses on the status of transportation weather issues in the nation and the results achieved since the first WIST report in 2002. It also highlights areas where further steps can be made in the near term.

AVIATION WEATHER

A project which is underway in the area of aviation weather support includes the development of *The National Volcanic Ash Operations Plan for Aviation and Support of the International Civil Aviation Organization International Airways Volcano Watch (NVOPA)*. This plan, projected be completed in the fall of 2006, is the national operations plan in support of observing, tracking, monitoring, forecasting and reporting volcanic ash in the atmosphere that affects the safety of flight operations in the U.S. National Airspace System (NAS). It identifies the federal agencies that implement these actions and describes their responsibilities, procedures, actions, and message formats.

The OFCM continues to facilitate the continuation of interagency funding for the acquisition of automated meteorological observations from aircraft in partnership with several major U.S. commercial airlines.

The OFCM continued to implement the National Aviation Weather Program during FY 2006. The federal interagency *National Aviation Weather Program* has resulted in a major reduction of weather-related accidents. The program remains on track toward meeting the established goal to reduce weather-related accidents by 80 percent by 2007. The OFCM continues to monitor progress in meeting this goal by monitoring weather-related aviation accident events and trends. *A National Aviation Weather Program Mid-Course Assessment* was completed in August 2003. OFCM will complete a final assessment in 2007, the ten year point of the National Aviation Weather Program.

SPACE WEATHER

It was noted at the November 16, 2004, and December 1, 2004, meetings of the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) and Federal Committee for Meteorological Services and Supporting Research (FCMSSR), respectively, that the National Space Weather Program (NSWP) was nearing the end of its 10-year period to accomplish its overarching goal to achieve an active, synergistic, interagency system; providing timely, accurate, and reliable space weather warnings, observations, specifications, and forecasts by 2007. It was also noted that it was time to perform an interagency assessment to look at the progress toward meeting its goals. A National Space Weather Program Assessment Committee was formed by OFCM to perform the assessment, which was led by Dr. Louis J. Lanzerotti, Distinguished Research Professor, Center for Solar-Terrestrial Research, New Jersey Institute of Technology.

In its *Report of the Assessment Committee for the National Space Weather Program* (June 2006), the Assessment Committee concluded that, since the program's inception in 1995, it has had a number of noteworthy achievements, most of which likely would not have been attained without the program's existence. The committee also found shortfalls in the program. Based on the conclusions of the committee as contained in the report, continuation of the NSWP is strongly warranted because of the enormous potential to enhance the nation's space weather mission over the next 10 years through improved operational capabilities, which capitalize on the transition of innovative research. The committee made specific recommendations to further strengthen the NSWP in four key areas.

It was agreed that the *Report of the Assessment Committee for the National Space Weather Program* should proceed for consideration by the National Space Weather Program Council (NSWPC), and that the Program Council should be the executive agent for FCMSSR for continuing activities in this area.

PHASED ARRAY RADAR

The OFCM Joint Action Group for Phased Array Radar Project (JAG/PARP) recently completed the report, *Federal Research and Development Needs and Priorities for Phased Array Radar* (June 2006). In the MPAR national vision, the National Radar Network will be the critical observing system supporting public safety, homeland security, and the transportation sector for decades to come; there is a need to replace the aging fleet of 526 conventional mechanically scanning radars over the next 20 years with 300+ MPAR radars; MPAR can provide simultaneous air and weather surveillance from a single radar site; and with the consolidation of multiple single-mission radars into MPAR we can reduce the national radar fleet by more than 40 percent. The JAG/PARP has determined that MPAR has the potential to exceed present radar capabilities and meet stated user needs; there would be a significant increase in tornado lead times; there are no serious hardware technical challenges; and a 7- to 10-year intensive research and development effort will be required, and the estimated cost of this is $200 million.

The report *Federal Research and Development Needs and Priorities for Phased Array Radar* estimated needed research and development funding to be $215 million over 9 years to meet the replacement opportunity. This would support the research needed to reduce risk, determine the capability of MPAR to meet multiple user needs

concurrently, develop a full MPAR prototype, and perform a cost analysis to determine system affordability.

ATMOSPHERIC RESEARCH AND DATA ASSIMILATION/DATA MANAGEMENT

Advances in data assimilation are key to meeting virtually any forecast goal relating to model performance. It was stated in the *Strategic Plan for the U.S. Integrated Earth Observation System* (April 2005) that "In order to take the 'pulse of the planet,' we must establish a valid end-to-end process that will take us from observations to user-related products. Scientific needs for this end-to-end process require that we … assimilate the Earth observation data streams into models (eventually in real time) …" and "Data assimilation may be the most critical path through which advances in forecasting convective precipitation will be modulated." At its November 16, 2004, meeting, the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) supported action to examine gaps in data assimilation and data management capability, articulate challenges that lie ahead in meeting future requirements, and propose strategy to address gaps in capability and future challenges.

The data assimilation survey and follow-on strategy was briefed at the July 18, 2006, ICMSSR meeting. It was noted that the focus of the report which is being prepared is on data assimilation for the purpose of improving forecast skill of a numerical weather prediction (NWP) model; the scope of data assimilation is restricted to incorporation of observational data as a forcing factor in cycles of forward NWP models; and broader definition of data assimilation would be addressed through inclusion of related activities such as climate reanalysis, trace constituent monitoring, and air quality.

Data gathering and data assimilation activity analysis tasks are essentially complete; the report framework and key issues have been defined by the data assimilation group; and next steps are being defined. The report, *Federal Meteorological Data Assimilation Capabilities*, will be published in the fall of 2006.

ENVIRONMENTAL LITERACY

OFCM has laid out a vision, framework, and methodology which the office will embrace to systematically promote and execute environmental literacy through interdepartmental collaboration within the OFCM coordinating infrastructure. The methodology defines how to determine if an opportunity to promote environmental literacy exists. It also describes the method to be used to determine the target public, private, and/or academic sector audiences and how to reach them. The OFCM developed an implementing strategy/action plan to make environmental literacy a crosscutting priority within the OFCM coordinating infrastructure. *An Implementing Strategy for Promoting Environmental Literacy as an OFCM Crosscutting Priority* was presented to the science community at the American Geophysical Union (AGU) Fall Meeting, December 5-9, 2005, in San Francisco, California.

FREQUENCY MANAGEMENT

Both international and domestic spectrum policy are of critical importance to the federal meteorological community and can significantly impact our ability to carry out our assigned duties and responsibilities. The OFCM Working Group for Frequency (Radio Spectrum) Management (WG/FM) acts as a two-way clearinghouse for information on environmental use of the radio spectrum. It fosters cooperation and coordination among federal agencies for the collection and consolidation of agency needs and requirements related to frequency management issues as they affect meteorological services, and planned non-environmental spectrum uses that may affect the environmental community for good or ill. During the first quarter of FY 2006, OFCM updated its frequency management issues document to provide the interagency community with background information, current status of meteorological uses, potential future technology that could impact spectrum bandwidth, identification of other new frequency management issues, and recommendations for agency involvement in the radio spectrum area.

GUIDANCE AND PRACTICES FOR XML

The recently formed Committee for Environmental Information Systems and Communications (CEISC) Joint Action Group for Extensible Markup Language and Web Services (JAG/XMLWS) reviewed the members' current Meteorological and Oceanographic (METOC) XML implementations and agreed to use DOD's Joint METOC Broker Language (JMBL) as a starting point for a U.S. position. A *Report on the use of XML within the U.S.* was presented to the Expert Team on Data Representation and Codes (ET/DR&C) at its meeting May 8-12, 2006. ET/DR&C is currently tasked by World Meteorological Organization's (WMO) Commission for Basic Systems (CBS) to develop XML guidance, practices, and any associated WMO standards for the representation and delivery of meteorological information using XML. The ET/DR&C recommended that CBS create a new Expert Team to tackle the XML standardization issue.

COLLABORATION WITH NAS/NRC BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE

The OFCM continued its mutually beneficial interactions with the

National Academy of Sciences/National Research Council (NAS/NRC). The NAS/NRC Board on Atmospheric Sciences and Climate (BASC) conducted a strategic planning workshop on August 8-9, 2006, in which the Federal Coordinator for Meteorology participated.

COLLABORATION WITH THE COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES

CENR PRINCIPALS

The Federal Coordinator continued to be a participant on the CENR, and continued to assist CENR through review and concurrence of CENR reports and materials.

SUBCOMMITTEE ON DISASTER REDUCTION

The OFCM has been an active participant in the work of the CENR Subcommittee on Disaster Reduction (SDR). OFCM is committed to working with SDR to provide a forum for information sharing, development of collaborative opportunities, and interactive dialogue with the U.S. policy community to advance informed strategies for managing risks associated with natural and technological disasters.

AMERICAN METEOROLOGICAL SOCIETY

During FY 2006, the OFCM joined in supporting the new 2006/2007 American Meteorological Society (AMS) Freshman Undergraduate Scholarship Program. The scholarship program is open to all high school students and designed to encourage study in the atmospheric and related sciences. The OFCM also supports AMS endeavors by participating in AMS conferences and workshops and other environmental science education and outreach programs. In addition, an OFCM staff member is Chairperson of the AMS Weather Analysis and Forecasting Committee; Cochair of the 2007 AMS Annual Meeting to be held in San Antonio, Texas; and a member of the AMS Reichelderfer Award Committee.

INTERNATIONAL COLLABORATION

During FY 2005, the Federal Coordinator provided a comprehensive briefing on the OFCM and interagency coordination of federal meteorological activities to Dr. Xu Xiaofeng and a delegation of 25 individuals from the Chinese Meteorological Administration, on May 24, 2005. Then on August 24, 2005, the Federal Coordinator hosted and briefed Dr. Zheng Guoguang, Deputy Administrator of the Chinese Meteorological Administration. Also, news media from Japan attended and conducted interviews at the 59th Interdepartmental Hurricane Conference in Jacksonville, Florida, March 7-11, 2005.

PUBLICATIONS AND OFCM'S WEB SITE

The following publications were prepared in hardcopy form and/or have been placed on OFCM's Web site (www.ofcm.gov):

- *The Federal Plan for Meteorological Services and Supporting Research-Fiscal Year 2006*

- *National Winter Storms Operations Plan*

- *National Hurricane Operations Plan*

- *Federal Research and Development Needs and Priorities for Phased Array Radar*

- *Report of the Assessment Committee for the National Space Weather Program*

- *Weather Information for Surface Transportation-Update on Weather Impacts and WIST Results*

- *Federal Meteorological Handbook No. 1-Surface Weather Observations and Reports*

- *Federal Meteorological Handbook No. 11-Doppler Radar Meteorological Observations; Part A-System Concepts, Responsibilities and Procedures*

- *Federal Meteorological Handbook No. 11-Doppler Radar Meteorological Observations; Part B-Doppler Radar Theory and Meteorology*

- *Federal Meteorological Handbook No. 11-Doppler Radar Meteorological Observations; Part D-WSR-88D Unit Description and Operational Analysis*

During FY 2006, the OFCM continued to make substantial progress on its use of the Internet. In addition to information about the office, the OFCM has placed its current publications on its Web site, and keeps the Web site current with information regarding workshops and forums being conducted by the office. The OFCM will continue to make information available on the Internet during FY 2007.

SECTION 1

ROADMAP FOR TROPICAL CYCLONE RESEARCH TO MEET OPERATIONAL NEEDS

INTRODUCTION

The 2005 hurricane season in the North Atlantic and Caribbean region set records for damage to the U.S. mainland. Although the 2006 hurricane season has not been as active as the 2005 season, landfalling hurricanes continue to be a threat to a large segment of our population due to the increase in density and economic infrastructure in coastal regions and the potential havoc these severe cyclonic storms can have inland due to tornadoes and flooding related to the decaying tropical cyclone (TC).

On July 10, 2005, Hurricane Dennis made landfall near Pensacola, Florida, with 105-knots winds and 10-foot storm surges. Florida residents were not strangers to hurricanes, as this was the fifth hurricane to hit Florida in less than a year. On August 25, 2005, Hurricane Katrina killed 14 in southeastern Florida when it brought heavy rains and winds to that region. On August 29th-30th, Katrina blasted the Louisiana and Mississippi coasts, coming onshore just east of New Orleans (Figure 1-1). Katrina's winds and massive flooding left thousands homeless, 2.3 million without electricity, roads and bridges destroyed, and communications inoperable. The storm surge caused by Katrina swamped the Mississippi Gulf Coast, destroying hundreds of homes, roads, and much of the coastal infrastructure. In Hurricane Katrina's wake, the estimated direct fatalities were 1,353, making it the third deadliest hurricane in the United States[1]. In addition to the catastrophic loss of life, Katrina also caused approximately $100 billion in losses.

Hurricane Rita struck the Florida Keys and the Gulf Coast in September following Katrina. On September 20, 2005, Hurricane Rita dumped heavy rains on the Florida Keys. It reached category 5 strength over the central Gulf of Mexico, but eventually weakened prior to making landfall as a category 3 hurricane at Sabine Pass near the Texas-Louisiana border. The strong storm surge and heavy winds caused major damage in the Louisiana and Texas coastal areas. Then, from October 18th to 24th, Hurricane Wilma ravaged Haiti, Jamaica, Cozumel, Cancun, Playa del Carmen, and eventually southern Florida. At one point, Wilma strengthened to category 5 on the Saffir-Simpson intensity scale for TCs, and on October 19th it became the deepest (lowest pressure) hurricane on record in the Atlantic, with a pressure dropping to 882 millibars. Wilma was the fourth storm in the 2005 season to reach category 5.

Operational forecast and warning capabilities require specialized atmospheric and oceanic observations from many platforms and sensors-both in situ and remote (Figure 1-2); specialized numerical weather prediction (NWP) models; highly trained people to develop and disseminate forecasts and warnings; and an active outreach program. Operational capabilities in each step of this end-to-end system have improved significantly since the inception of TC forecasting. The gains made over the past several decades in our understanding and forecasting of TCs have paralleled the improvements in observational capabilities, such as

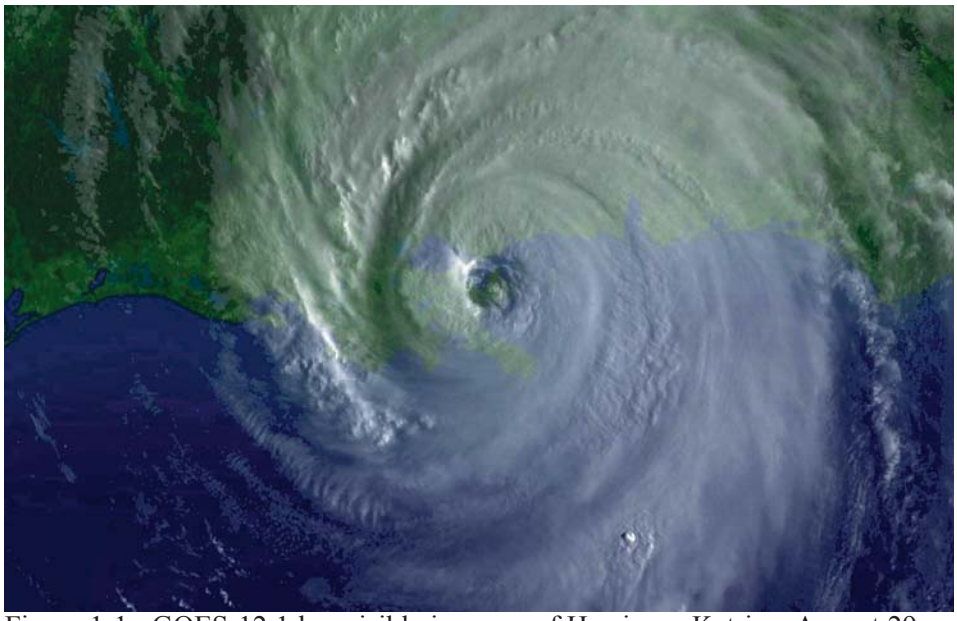


Figure 1-1. GOES-12 1 km visible imagery of Hurricane Katrina; August 29, 2005; 09:57:10. Credit: NOAA.

[1] This estimate as of May 15, 2006, is based on information from affected states' departments of health. The estimate includes direct fatalities only and does not include out-of-state evacuee fatalities included in some calculations. Fatalities by state: Louisiana 1,097; Mississippi 238; Florida 14; Alabama 2; and Georgia 2.

Article prepared by Mr. Mark Welshinger, OFCM staff.

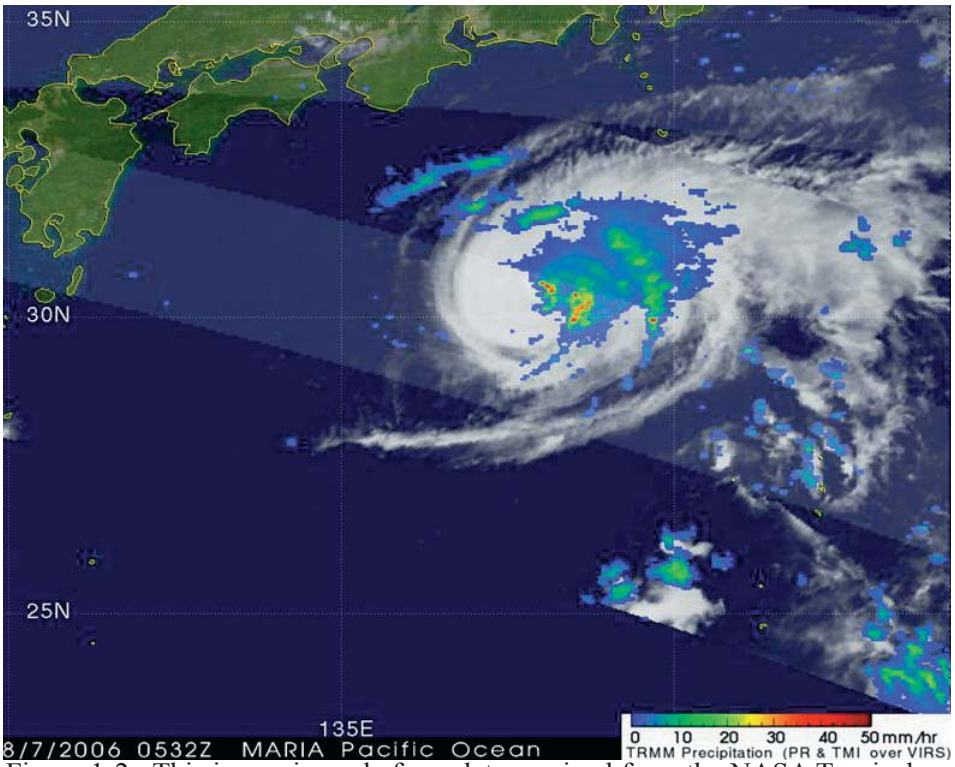


Figure 1-2. This image is made from data received from the NASA Tropical Rainfall Measurement Mission (TRMM) satellite showing Typhoon Maria closing in on Japan (August 7, 2006). Typhoon Maria subsequently weakened and passed just south of Tokyo Bay as a minimal tropical storm. Credit: NASA.

U.S. Air Force Reserve Command (53rd Weather Reconnaissance Squadron-the Hurricane Hunters) and National Oceanic and Atmospheric Administration (NOAA) instrumented aircraft (e.g., GPS dropwindsondes, stepped-frequency microwave radiometers [SFMR], airborne tail Doppler radar), satellite data, moored and drifting buoys, subsurface floats, land-based Doppler radars). The gains made in forecasting of TCs have also paralleled improvements in NWP model physics and the increased use of observations through more sophisticated data assimilation capabilities to provide improved initial conditions for the models. Nevertheless, further improvement to the Nation's TC forecast and warning service through focused research and development (R&D) are feasible, within reach, and valuable investments for our safety, security, and economic well-being. The purpose of this article is to review three projects regarding TC R&D. The projects share an ultimate goal which is to prevent loss of life and injuries associated with TCs and to reduce the Nation's vulnerability to these potentially devastating storms. Before reviewing the projects, a review of the operational TC forecast and warning centers is warranted.

OPERATIONAL TC FORECAST AND WARNING CENTERS

The TC warning service is an interdepartmental effort to provide the U.S. and designated international recipients with forecasts, warnings, and assessments concerning tropical and subtropical weather systems. The three centers that cooperate to provide this service are discussed below. Figure 3 shows the areas of responsibility for TC forecasts and warnings for the three centers: the Tropical Prediction Center/National Hurricane Center (TPC/NHC), the Central Pacific Hurricane Center (CPHC), and the Joint Typhoon Warning Center (JTWC).

TPC/NHC

The TPC is one of the twelve centers comprising the National Centers for Environmental Prediction (NCEP), a component of the NOAA National Weather Service (NOAA/NWS). Located at Florida International University in Miami, Florida, the TPC is the Regional Specialized Meteorological Center (RSMC) designated by the World Meteorological Organization (WMO) for the North Atlantic Ocean, including the Caribbean Sea and Gulf of Mexico, and the eastern North Pacific Ocean, east of longitude 140 degrees W. The TPC provides general weather guidance, as well as specialized products for aviation and marine interests in the tropics. A substantial amount of TPC/NHC's NWP model support comes from NCEP's Environmental Modeling Center. Both the TPC/NHC and the CPHC take their mission direction from the *National Hurricane Operations Plan*.

One of three major components of the TPC is the National Hurricane Center (NHC). The NHC maintains a continuous watch on TCs from May 15th in the northeastern Pacific and from June 1st in the north Atlantic through November 30th.

JTWC

The JTWC is a joint Air Force/Navy TC forecasting center. Located at Naval Base Pearl Harbor, Hawaii, the JTWC is the Department of Defense (DOD) agency responsible for issuing TC warnings for the Pacific and Indian Oceans. JTWC support encompasses more than 110 million square miles of the north and south Pacific Ocean and Indian Ocean, reaching from the west coast of the Americas to the east coast of Africa. The JTWC takes its mission direction from the Commander, U.S. Pacific Command Instruction 3140.1w (version 1w is the latest in the series). A substantial amount of JTWC's NWP model support comes from the Naval Research Laboratory (NRL) and Fleet

Numerical Meteorology and Oceanography Center (FNMOC), both located in Monterey, California.

CPHC

CPHC has forecast and warning responsibility for the central North Pacific from 140 degrees W longitude to the International Date Line. The CPHC is a component of the NOAA/NWS Weather Service Forecast Office (WFO), Honolulu, Hawaii (Figure 1-3). The Meteorologist-In-Charge, WFO Honolulu, is also the Director of the CPHC. Because the WFO Honolulu has no authorized manpower for the specialized hurricane operations of the CPHC, the center is activated only when a TC crosses into the area between 140 degrees W longitude and the International Date Line. On July 1, 2001, the WFO Honolulu was designated a WMO RSMC. Most outside support, such as model and techniques development and aerial reconnaissance, is provided through the same infrastructure that supports the TPC/NHC.

OFCM-SPONSORED PROJECT

The OFCM hosts the annual Interdepartmental Hurricane Conference (IHC), which provides a forum for the Federal agencies with operational and R&D responsibilities related to TCs, together with emergency managers and other representatives of the agencies' user communities, to review the Nation's TC forecast and warning program and make recommendations on how to improve the program in the future. One of the major objectives is to plan and prepare for the upcoming hurricane season. New procedures, procedural changes, and agreements that are approved at the IHC and are directly related to providing TC forecast and warning services are then documented for implementation in the *National Hurricane Operations Plan*. The following functional areas have been routinely included in recent IHC agendas:

- TC observations and reconnaissance.
- TC modeling and prediction.
- Impacts of TCs (e.g., winds, storm surge, heavy precipitation/inland flooding).
- TC research; science and technology.
- Transitioning TC research to operations.
- TC decision-making products and services.
- TC warning system and response.

One of the action items from the 58th IHC was to develop a comprehensive strategy for TC R&D to guide interagency efforts over the next decade. Subsequently, the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) strongly supported this action. To implement the action, the Federal Coordinator for Meteorology formed the Joint Action Group for TC Research (JAG/TCR). The vision of the JAG/TCR is to maximize the potential of the TC community partnerships to improve hurricane prediction, preparedness, and resiliency for societal benefit by strategically matching research results to operational requirements. The JAG/TCR members agreed that past research planning efforts clearly outlined the TC community's priorities, objectives, and strategies, as developed and vetted through many meetings and workshops. **Therefore, the task of the JAG/TCR has been to synthesize the previous exceptional TC work, update information as needed, and develop and coordinate a comprehensive interagency strategic research plan for TCs that links research priorities to operational needs.**

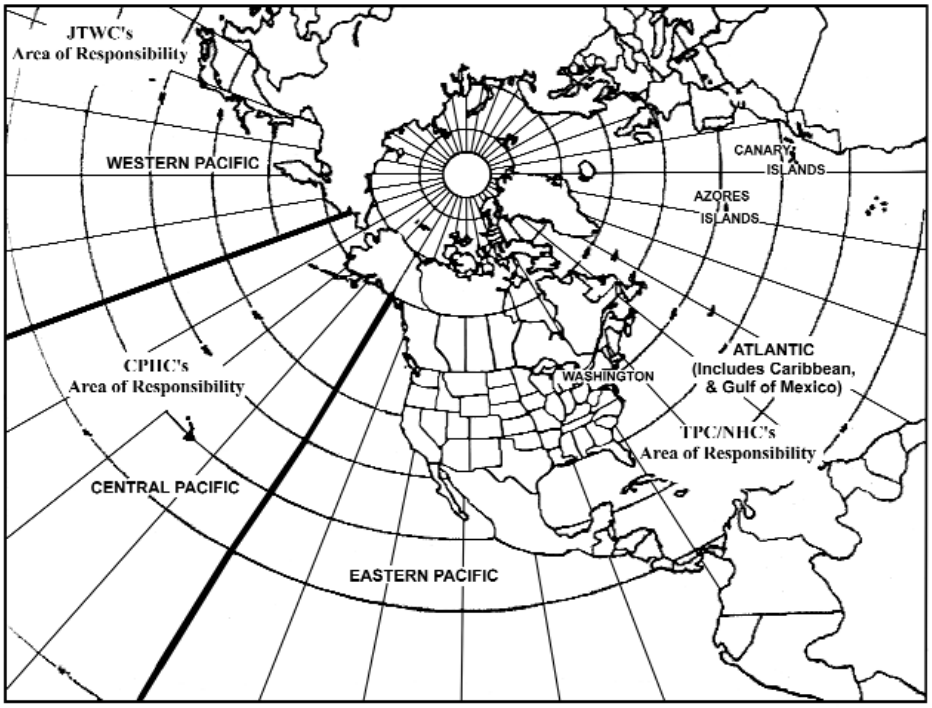


Figure 1-3. Areas of responsibility assigned to national operational forecast and warning centers. Courtesy of NOAA.

CONCURRENT TC-RELATED R&D PROJECTS

At the request of the Under Secretary of Commerce for Oceans and Atmosphere, the NOAA Science Advisory Board (SAB) formed an external group to conduct a review of NOAA's hurricane intensity research, development, and transition to operations. The panel became known as the NOAA SAB Hurricane Intensity Research Working

Group (HIRWG). In another hurricane-related project, the National Science Board (NSB), the governing board of the National Science Foundation (NSF), formed the Task Force on Hurricane Science and Engineering (HSE). The task force examined the "hurricane problem" in a more holistic manner, considering physical, social, behavioral, economic, biological, ecological, information technology, and other appropriate sciences, as well as engineering (e.g., civil, environmental, mechanical) disciplines. Two questions incorporated into their review were:

1. To what extent does the Nation understand the hurricane as an integrated science and engineering problem?
2. How can such understanding be used to improve the Nation's ability to predict, mitigate, and react?

To ensure that these three efforts-NOAA/SAB, NSF/NSB, and OFCM's JAG/TCR-were aware of, and able to learn from, each other, the OFCM planned a workshop during the 60th IHC, held in Mobile, Alabama, entitled *Tropical Cyclone Research: Priorities for the Next Decade*. The workshop was moderated by Dr. Robert Serafin, National Center for Atmospheric Research Director Emeritus and Chair of the Board on Atmospheric Sciences and Climate. Dr. Michael Crosby, Executive Officer for the NSF/NSB, provided an update on the Task Force on HSE. Following Dr. Crosby, Dr. John Snow, College of Geosciences, University of Oklahoma, presented an update on activities of the NOAA/SAB HIRWG. The last item in the research workshop was a review of an early version of the JAG/TCR's draft interagency strategic research plan for TCs. Dr. Frank Marks (NOAA/AOML /HRD) and Ms. Robbie Hood (NASA Marshall Space Flight Center, Global Hydrology and Climate Center), cochairs of OFCM's JAG/TCR, along with Dr. Naomi Surgi (NOAA/NWS /NCEP/EMC), led this portion of the workshop. The workshop was of great benefit to all three project groups, and other participants at the workshop were able to hear about, and interact concerning, these complementary ongoing efforts.

MORE DETAILS ON THE JAG/TCR WORK

In addition to the workshop held at the IHC (described above), the JAG/TCR kept abreast of the work of the two other projects. This section provides additional details of the work of the JAG/TCR and their document, *Interagency Strategic Research Plan for Tropical Cyclones*: *The Way Ahead.* The plan:

- Illustrates the fundamental rationale for continuing the effort in TC R&D that has produced major improvements in forecasts and warnings in recent years. It introduces the R&D community that supports the three operational TC forecast and warning centers.
- Describes in more detail the major players in the TC R&D community and how they interact with each other and with the operational centers. It also reviews recent and concurrent planning activities that are significant for formulating a community strategy.
- Assesses the Nation's current capability and limitations of the Nation's TC warning service. These capabilities constitute a classic end-to-end system for environmental observing, modeling and interpretation, communication of products and information, and end-user education and outreach-albeit one focused on the environmental threats posed by TCs. The capabilities assessment therefore begins with the key operational observing systems, progresses to the operational models and systems for assimilating data into them, and then discusses the forecast and warning information dissemination system, including current efforts in end-user education and outreach.
- Uses the same end-to-end system structure to present the JAG/TCR's perspective on the future capabilities required to meet both current operational needs and emerging needs identified by the operational centers. The future capabilities section reviews several potential improvements to the observational capabilities, including the National Aeronautics and Space Administration's Global Precipitation Measurement Satellite, the Constellation of Observing Satellites for Meteorology, Ionosphere, and Climate (COSMIC) satellites (see Figure 1-4), and land-based Multifunction Phased Array Radar (MPAR). The future capabilities section also reviews DOD and NOAA NWP plans. These future capabilities are translated into a set of research priorities, around which a comprehensive R&D strategy for the next decade can be built.

The overarching research priorities established by the JAG/TCR included tropical cyclone intensity and structure (wind radii); track; other landfalling impacts (sea state and storm surge, precipitation, and inland flooding); social science research; and intraseasonal and inter-annual variability.

- Presents the JAG/TCR recommendations for next steps that can be taken by the cognizant Federal agencies and coordinating entities to begin implementation of this strategy.

SUMMARY

While tropical cyclone forecasting has been and continues to be a challenge, as we move forward over the next decade we can expect continued improvements in TC forecasting. As detailed in the *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead,* the capability to gain skill in forecasting intensity and structure, sea state and storm surge, and precipitation is now on the horizon much

like improving track was a decade ago. The gain in skill is due to continued improvements in observational capabilities and further advancements in NWP model physics and data assimilation systems.

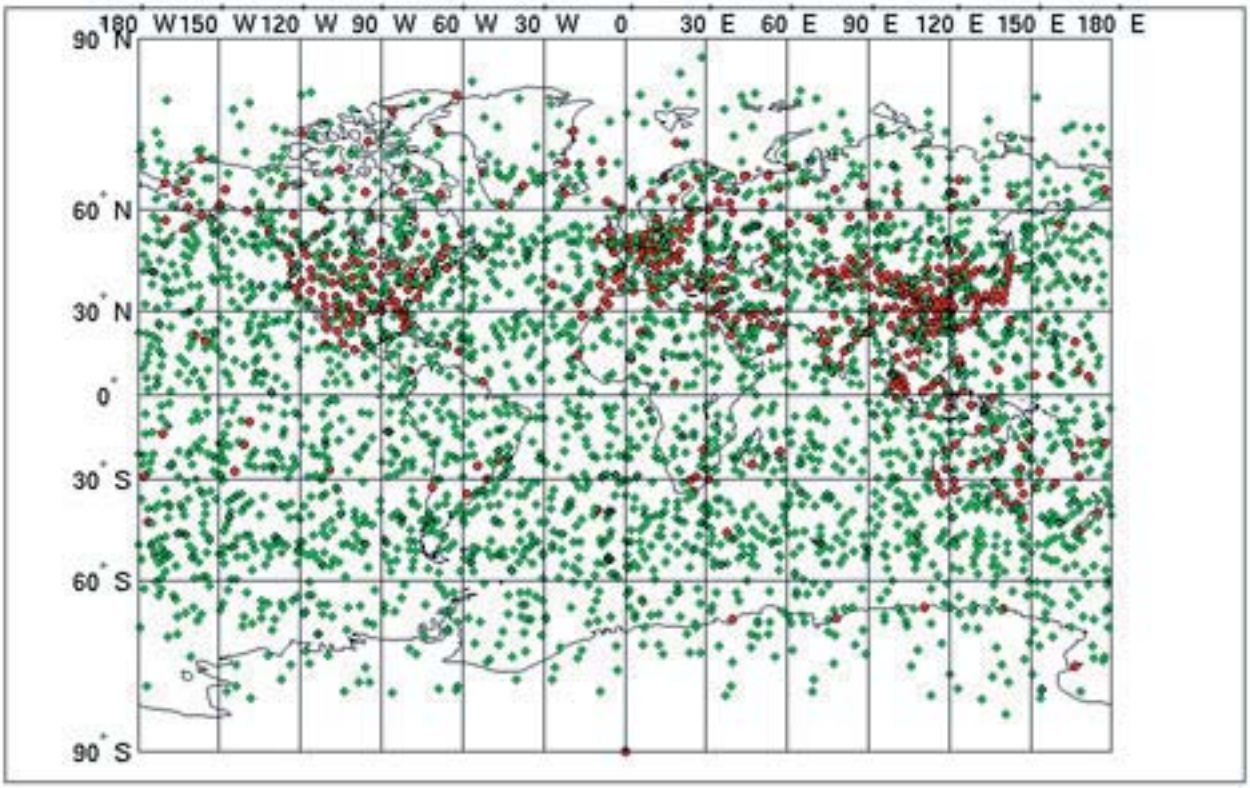


Figure 1-4. A comparison of the current global coverage of instruments launched via radiosondes each day (in red) with the expected coverage from the COSMIC satellite network in a 24-hour period (in green). Credit: COSMIC.

SECTION 2

RESOURCE INFORMATION AND AGENCY PROGRAM UPDATES

The tables in this section summarize budgetary information of the Federal government for Fiscal Years 2006 and 2007. The funds shown are those used to provide meteorological services and associated supporting research that has as its immediate objective the improvement of these services. Fiscal data are current as of the end of August 2006 and are subject to later changes. The data for FY 2007 do not have legislative approval and do not constitute a commitment by the United States Government. The budget data are prepared in compliance with Section 304 of Public Law 87-843, in which Congress directed that an annual horizontal budget be prepared for meteorological programs conducted by the Federal agencies.

AGENCY OBLIGATIONS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

Table 2.1 contains fiscal information, by agency, for meteorological operations and supporting research. The table shows the funding level for Fiscal Year (FY) 2006 based on Congressional appropriations, the budget request for FY 2007, the percent change, and the individual agencies' percent of the total Federal funding for FY 2006 and FY 2007.

DEPARTMENT OF AGRICULTURE (USDA)

The USDA budget request for FY 2007 is $51.1 million for operations and supporting research, representing a 14.7 percent decrease from FY 2006. A large portion of this decline was due to a reduction in funding for supporting research. USDA has requested a total $31.4 million for research and development programs, an $8.3 million decrease from 2006. The FY 2007 amount requested for meteorological operations is $19.7 million, down from $20.2 million in FY 2006.

Operational activities include specialized weather observing networks such as the SNOTEL (SNOw pack TELemetry) system operated by the Natural Resources Conservation Service (NRCS) and the remote automated weather stations (RAWS) network managed by the Forest Service. The SNOTEL and RAWS networks provide cooperative data for NOAA's river forecast activities, irrigation water supply estimates, and Bureau of Land Management operations. The Forest Service is also the world leader in developing emissions factors from fires and modeling its dispersion. The USDA and the Department of Commerce (DOC) jointly operate a global agricultural weather and information center located in Washington, D.C. This Joint Agricultural Weather Facility operationally monitors global weather conditions and assesses the impacts of growing season weather on crop and livestock production prospects. This information keeps crop and livestock producers, farm organizations, agribusinesses, state and national farm policy-makers, government agencies, and foreign buyers of agricultural products apprised of worldwide weather-related developments and their effects on crops and livestock. Furthermore, tracking weather and crop developments in countries that are either major exporters or importers of agricultural commodities keeps the agricultural sector informed on potential competitors. USDA is also actively involved in drought monitoring efforts in concert with the National Drought Mitigation Center.

For supporting research, USDA funds research projects through the Cooperative State Research, Education and Extension Service (CSREES) that study the impact of climate and weather on food and fiber production. The goal of supporting research is to develop and disseminate information and techniques to ensure an abundance of high-quality agricultural commodities and products while minimizing the adverse effects of agriculture on the environment. Furthermore, the Agricultural Research Service (ARS) conducts research on how annual variation in weather adversely effects crop and animal production, hydrologic processes, the availability of water from watersheds, and the environmental and economic sustainability of agricultural enterprises.

DEPARTMENT OF COMMERCE (DOC)

All reported DOC meteorological activities are within the National Oceanic and Atmospheric Administration (NOAA). The NOAA FY 2007 total congressional request of $2.04 billion for meteorological programs represents an increase of 4.2 percent over the FY 2006 appropriated funds. NOAA's FY 2007 operations and supporting research requests for major line office activities are described below:

WEATHER SERVICES

The National Weather Service (NWS) provides weather, hydrologic, and climate forecasts and warnings for the U.S., its territories, adjacent waters, and ocean areas for the protection of life and property and the enhancement of the national economy.

TABLE 2.1 METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH COSTS*, BY AGENCY

(Thousands of Dollars)

	Operations			% of FY2007	Supporting Research			% of FY2007	Total			% of FY2006	% of FY2007
AGENCY	FY2006	FY2007	%CHG	TOTAL	FY2006	FY2007	%CHG	TOTAL	FY2006	FY2007	%CHG	TOTAL	TOTAL
Agriculture	20201	19710	-2.4	0.7	39706	31395	-20.9	7.6	59907	51105	-14.7	1.8	1.5
Commerce/NOAA(Subtot)	1838032	1954209	6.3	64.5	122824	89787	-26.9	21.7	1960856	2043996	4.2	59.1	59.3
NWS	848244	881866	4.0	29.1	21057	22130	5.1	5.3	869301	903996	4.0	26.2	26.2
NESDIS	952220	1033883	8.6	34.1	31753	24771	-22.0	6.0	983973	1058654	7.6	29.7	30.7
OAR	0	0	0	0.0	68358	41230	-39.7	10.0	68358	41230	-39.7	2.1	1.2
NOS	24078	24970	3.7	0.8	500	500	0.0	0.1	24578	25470	3.6	0.7	0.7
NMAO	13490	13490	0.0	0.4	1156	1156	0.0	0.3	14646	14646	0.0	0.4	0.4
Defense(Subtot)	503983	514056	2.0	17.0	87220	89369	2.5	21.6	591203	603425	2.1	17.8	17.5
Air Force	309401	317089	2.5	10.5	28675	34899	21.7	8.4	338076	351988	4.1	10.2	10.2
DMSP**	84121	103885	23.5	3.4	3852	969	-74.8	0.2	87973	104854	19.2	2.7	3.0
Navy	59288	47786	-19.4	1.6	41427	42581	2.8	10.3	100715	90367	-10.3	3.0	2.6
Army	51173	45296	-11.5	1.5	13266	10920	-17.7	2.6	64439	56216	-12.8	1.9	1.6
Homeland Security (Subtot)	19340	20110	4.0	0.7	0	0	0.0	0.0	19340	20110	4.0	0.6	0.6
USCG	19340	20110	4.0	0.7	0	0	0.0	0.0	19340	20110	4.0	0.6	0.6
Interior/BLM	2400	2400	0.0	0.1	0	0	0.0	0.0	2400	2400	0.0	0.1	0.1
Transportation(Subtot)	483316	518624	7.3	17.1	25706	27800	8.1	6.7	509022	546424	7.3	15.3	15.9
FAA	483027	518335	7.3	17.1	21506	23600	9.7	5.7	504533	541935	7.4	15.2	15.7
FRA	289	289	0.0	0.0	0	0	0.0	0.0	289	289	0.0	0.0	0.0
FHWA	0	0	0.0	0.0	4200	4200	0.0	1.0	4200	4200	0.0	0.1	0.1
EPA	0	0	0.0	0.0	9000	9000	0.0	2.2	9000	9000	0.0	0.3	0.3
NASA	2394	2463	2.9	0.1	162800	166400	2.2	40.2	165194	168863	2.2	5.0	4.9
NRC	120	120	0.0	0.0	0	0	0.0	0.0	120	120	0.0	0.0	0.0
TOTAL	2869786	3031692	5.6	100.0	447256	413751	-7.5	100.0	3317042	3445443	3.9	100.0	100.0
% of FY TOTAL	86.5%	88.0%			13.5%	12.0%			100.0%	100.0%			

*The FY 2006 funding reflects Congressionally appropriated funds; the FY 2007 funding reflects the amount requested in the President's FY 2007 budget submission to Congress.

**DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

NWS data and products form a national information database and infrastructure which can be used by other government agencies, the private sector, the public, and the global community.

The U.S. is one of the most severe-weather prone countries on Earth. Each year, Americans cope with an average of 10,000 thunderstorms, 5,000 floods, 1,200 tornadoes, as well as 6 deadly hurricanes. Some 90 percent of all Presidentially-declared disasters are weather related, causing approximately 500 deaths per year and $14 billion in damage. According to the American Meteorological Society, weather is directly linked to public safety and about one-third of the U.S. economy (about $3 trillion) is weather sensitive.

More and more sectors of the U.S. economy recognize the impacts of weather, water, and climate on their businesses, and are becoming more sophisticated at using weather, water, and climate information to make better decisions. To meet this growing demand for information and to improve the timeliness and accuracy of warnings for all weather related hazards, the NWS will continue to enhance observing capabilities, improve data assimilation to effectively use all the relevant data NWS and others collect, improve collaboration with the research community, make NWS information available quickly, efficiently, and in a useful form (e.g., the National Digital Forecast Database) and include information on forecast uncertainty to help customers make fully informed decisions.

With about 4,800 employees in 122 weather forecast offices (WFO), 13 river forecast centers, 9 national centers and other support offices around country, NWS provides a national infrastructure to gather and process data worldwide from the land, sea, and air. This infrastructure enables data collection using technologies such as Doppler weather radars, satellites operated by NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), data buoys for marine observations, surface observing systems, and instruments for monitoring space weather and air quality. These data feed sophisticated environmental prediction models running on high-speed supercomputers. Our highly trained and skilled workforce uses powerful workstations to analyze all of these data to issue climate, public, aviation, marine, fire weather, air quality, space weather, river and flood forecasts and warnings around-the-clock. A high-speed communications hub allows for the efficient exchange of these data and products between NWS components, partners and customers. NWS forecasts and warnings are rapidly distributed via a diverse dissemination infrastructure including NOAA Weather Radio. Finally, customer outreach, education, and feedback are critical elements to effective public response and improvements to NWS services.

The FY 2007 President's Budget Request supports the funding and program requirements necessary to address established NOAA strategic goals and sets NWS on a path to achieve its vision: *Produce and deliver forecasts that can be trusted; use cutting-edge technologies; provide services in a cost-effective manner; strive to eliminate weather related fatalities; and improve the economic value of weather, water, and climate information.*

NOAA requests a total of $903,996,000 million and 4,606 FTE to support the continued and enhanced operations of the National Weather Service. The total includes $24,754,000 for Adjustments to Base, $37,445,000 million for Program Increases, and $25,597,000 in Terminations.

ADJUSTMENTS TO BASE:

NOAA requests a net increase of $24,754,000 and 0 FTE to fund adjustments to base across all accounts in the National Weather Service activities. With this increase, program totals will fund the estimated FY 2007 Federal pay raise of 2.2 percent and annualize the FY 2006 pay raise of 3.1 percent. Program totals will provide inflationary increases for non-labor activities, including service contracts, utilities, field office lease payments, and rent charges from the General Services Administration.

NWS also requests the following transfers between line offices or appropriations for a net change to NOAA of zero:

- $2,291,000 is transferred from the National Tsunami Hazard Mitigation Program to the Strengthen the U.S. Tsunami Warning Network Program Planning Activity (PPA) within the Local Warnings and Forecasts Line Item. This transfer has no net effect on overall NWS or NOAA funding and was done simply to consolidate all NWS Tsunami funding into one PPA.
- $3,000,000 is transferred from the Local Warning and Forecasts line to benefit the Oceanic and Atmospheric Research (OAR) Competitive Research Program.
- $21,500,000 is transferred from the National Data Buoy Center to the Local Warnings and Forecasts base and Alaska Data Buoy PPAs within the Local Warnings and Forecasts line item.
- $5,800,000 is transferred from the National Hurricane Center to the Central Forecasts Guidance PPA within the Central Forecasts Guidance line item.

NWS - ORF PROGRAM CHANGE HIGHLIGHTS FOR FY 2007:

NOAA requests a net increase of $37,445,000 and 9 FTE over the FY 2007 base for a total request of $783,446,000 and 4,606 FTE. These changes are summarized at the subac-

tivity level below and to be concise, do not include descriptions below $1,000,000. Descriptions of each request by line item are located in the NOAA FY 2007 Technical Budget.

Operations and Research
($687,856,000)

A net increase of $28,654,000 and 9 FTE above the base is requested in the Operations and Research subactivity, for a total of $687,856,000 and 4,424 FTE.

Local Warnings and Forecasts: $28,654,000 and 9 FTE in net increases above the base, for a total of $636,793,000 and 4,125 FTE, are requested under the Local Warnings and Forecasts line item of the Operations and Research subactivity.

• NOAA requests 0 FTEs and $1,400,000 to operate and maintain the seven new weather data buoys funded/deployed under the FY 2005 Hurricane Supplemental Appropriation. These buoys support enhanced real time hurricane data observations and storm monitoring in the Caribbean, Gulf of Mexico, and the Atlantic Ocean to support the NOAA hurricane warning and forecast mission. The FY 2005 Hurricane Supplemental provided one-time funding to procure and deploy these buoys. This program adjustment requests the funding required to support the long-term operation and maintenance of these platforms. This investment is required for NOAA's implementation of the Integrated Ocean Observing System (IOOS) as the coastal and open ocean component of the Global Earth Observation System of Systems (GEOSS). Combined with other like-identified IOOS investments across NOAA, it is part of NOAA's strategy to provide initial benefits of an integrated ocean observing system, focusing on enhancing key observational capabilities throughout NOAA, and our ability to provide customers with enhanced coastal data and information. The seven newly installed data buoys, consisting of one 3-meter, two 6-meter, two 10-meter, and two 12-meter buoys, require annual maintenance and shore-side operating/infrastructure support to maintain reliable data output. Funds will be used to provide: field service and maintenance; shore-side operation/infrastructure support; and to maintain spare equipment/buoy to support field maintenance strategy.

• NOAA requests $12,360,000 and 4 FTE to strengthen the U.S. tsunami warning program. In response to the 2004 Indian Ocean Tsunami, the Administration proposed expanding the U.S. Tsunami Warning Program to protect U.S. lives and property along all coasts (Pacific, Gulf of Mexico, Atlantic and the Caribbean). In order to continue the Administration's commitment to strengthening the U.S. Tsunami Warning Program and mitigate a similar seismic/tsunami event in the U.S., NOAA needs to build upon the foundation laid in FY 2005 and FY 2006 and continue to accelerate and improve its: (1) Tsunami Hazard Assessment Programs (including comprehensive coastal U.S. risk assessments/inundation mapping, modeling and forecasting efforts); (2) Tsunami Warning Guidance Programs (including 24/7 tsunami detection and warning systems and the dissemination of accurate and timely tsunami forecasts and warnings); and (3) Tsunami Mitigation Programs (including community-based emergency response plans) and public education/awareness (Tsunami Ready communities and inundation/evacuation mapping). Funds will be used to operate and maintain the newly expanded DART systems, new sea-level monitoring stations, the upgraded local seismic networks supporting the West Coast /Alaska Tsunami Warning Center (WC/ATWC) and the Richard H. Hagemeyer Pacific Tsunami Warning Center (PTWC), and to operate both the WC/ATWC and PTWC as 24/7 Operation Centers.

• NOAA requests $3,500,000 and 5 FTE to transfer the Wind Profilers from research to operations. Wind Profilers, vertical looking radars, installed in 1988, are used for a variety of analytical forecasting tasks. Wind profile data are used as input for numerical (computer) weather models that predict clouds, precipitation, and temperature. The data also provide important indicators of where severe weather such as tornadoes and winter storms may form, requiring weather advisories, watches, or warnings. Weather forecasters also use wind profiler data for issuing aviation Significant Meteorological (SIGMET) advisories and wildfire predictions. The NOAA Profiler Network (NPN) must be upgraded to operate at a different frequency because of interference with signals from new search and rescue (SAR) satellites expected to launch by the European Space Agency in FY 2006. Currently, the SAR beacons and the NPN operate at the same frequency. Consequently, the SAR beacon will interfere with NPN wind profiling radars whenever a satellite is overhead. The NPN wind profile information improves NWS operational warning and watch performance capability. Performance statistics indicate that tornado, winter storm, severe storm, flash flood forecasts and warnings, and aviation weather and fire weather warnings for NWS WFOs with wind profilers are more accurate and are able to provide longer warning lead-times. In FY 2007 NWS will: initiate engineering design and development contract for new frequency compliant transmitters; coordinate with data users the development of contingency plans for interference issues that may arise; and, provide operations and maintenance support for the current Profiler network.

• NOAA requests $1,200,000 and 0 FTE to expand the multi-year effort to improve aviation weather services. This requested increase will enable

procurement and fielding of 75 additional water vapor sensors as part of an Integrated Upper Air Observing system, and transition additional products to a digital environment. Today, weather accounts for 70 percent of all air traffic delays within the U.S. National Airspace System (NAS), resulting in a $10B impact to the U.S. economy, $4B of which the Federal Aviation Administration (FAA) has determined is preventable. The Aviation Weather program must continue to implement projects and training opportunities that improve both the accuracy of weather information and the way in which weather information is utilized. Pilots, controllers and flight planners require products in digital formats to facilitate and expand their use in the cockpit and to convey forecast specifics graphically lending to better, more informed decision making. The Aviation Program must be prepared to enable the NWS to transition and sustain FAA Research and Development (R&D) efforts in aviation weather that are valued over $24M/year. In addition, the Aviation Program is supporting the Joint Planning and Development Office (JPDO) effort to develop the Next Generation Air Transportation Systems (NGATS), with the Department of Commerce (DOC) leading a 5-agency [Department of Defense (DOD), Department of Transportation (DOT), Department of Homeland Security (DHS), National Aeronautics and Space Administration (NASA), and DOC] Weather Integrated Process Team.

• NOAA requests $2,500,000 and 0 FTE for the Air Quality Forecasting Program. This program provides air quality forecast guidance with the implementation of NOAA's Air Quality Forecast capability. This increase will be used for nationwide deployment of ozone forecasts in FY 2009, and for initial PM forecast capability in FY 2012. The air quality forecast capability for next-day ground-level ozone, first deployed operationally in September 2004, over the Northeastern U.S., and now covering the Eastern U.S., will be extended through phased development and testing nationwide in FY 2009.

• NOAA requests $3,199,000 and 0 FTE for the Space Environment Center. SEC provides real-time monitoring and forecasting of solar and geophysical events, conducts research in solarterrestrial physics, and develops techniques for forecasting solar and geophysical disturbances. SEC provides services to a broad user community of government agencies, industries, public institutions, and private individuals involved in satellite operation, space exploration, radio navigation, high-altitude polar flights, high-frequency communications, remote intelligence gathering, long-line power and data transmissions, and geophysical exploration.

• NOAA requests $890,000 and 0 FTE for the Cooperative Observer Program. This request funds Operations and Maintenance (O&M) support for NOAA legacy Cooperative Observer program. This program provides observational meteorological data in near real-time to support forecast, warning and other public service programs of the NWS. More than 11,000 volunteers take observations on farms, in urban and suburban areas, national parks, seashores, and mountaintops and the data that are collected are truly representative of where people live, work and play.

• NOAA requests $2,457,000 and 0 FTE for U.S. Weather Research Program. This request will accelerate hurricane research, air quality research for particulate matter forecasts, and to expand The Observing System Research and Predictability Experiment (THORPEX). The hurricane research activities include improving forecasts of hurricane intensity at landfall.

• NOAA requests $1,098,000 and 0 FTE for the Advanced Hydrological Prediction Services (AHPS). This funding allows continued nationwide implementation of AHPS, with deployment at an additional 309 forecast points in these areas. AHPS information comes from the combined use of remote sensing, data automation and advanced computer modeling to analyze river data, and create graphical displays of flood probability forecasts, including flood-forecast maps, pinpointing areas where flooding may occur. The FY 2007 budget also supports extramural partnerships to carry out operationally-oriented hydrologic research, deployment of new flash-flood forecasting tools, and introduction of more effective river forecasting models.

Systems Operation & Maintenance (O&M) $95,590,000

A net increase of $8,791,000 and 0 FTE above the base is requested in the Systems Operation & Maintenance subactivity, for a total of $95,590,000 and 182 FTE.

• NOAA requests an increase of $2,500,000 and 0 FTE, to implement a telecommunications network solution that resolves an existing single-point-of-failure associated with the NWS Telecommunications Gateway Critical Infrastructure Protection (NWSTG-CIP). This investment will ensure uninterrupted delivery of critical meteorological data necessary for the protection of life and property, and the economic well being of the Nation. The NWSTG-CIP is the hub for all NWS/NOAA weather, water and climate data and information, and has been identified as an essential government resource in Presidential Decision Directive - 67 Enduring Constitutional Government and Continuity of Government Operations. The geographically disparate backup system will be connected to the NWSTG primary and user community through a telecommunications network. Funds will be used

for operations and maintenance (O&M) in FY 2007 which includes annual recurring telecommunications costs for switching all NWSTG circuits through a switch located at the Local Exchange Carrier (LEC) central office. The Department of Commerce Chief Information Office (CIO) mandated that the connectivity between the NWSTG and NWSTG-CIP eliminates all single-points-of failure. In order for this to transpire, a network was designed to bypass the LEC central office. Without full network connectivity, the NWSTG will remain a single point of failure, risking the delivery of critical meteorological data necessary for the protection of life and property, vital to the economic well being of the Nation.

• NOAA requests $3,461,000 and 0 FTE for Advanced Weather Interactive Processing System (AWIPS). This request will fund continued operations and maintenance for the network of 169 fielded systems. AWIPS integrates satellite and NEXRAD Doppler weather radar data and provides to the local field forecaster capabilities to significantly improve forecasts and warnings.

• NOAA requests $2,830,000 and 0 FTE for NEXRAD. This request will restore funding necessary for continued operations and maintenance for the network of 123 NEXRAD systems. NEXRAD systems are critical for real-time observations and forecasts of severe weather events, including tornadoes, heavy precipitation, and hurricanes.

SYSTEMS ACQUISITION
($66,611,000)

NOAA requests a decrease of $2,440,000 and 0 FTE for a total of $1,030,000 to reflect the planned reduction in the procurement of program assets that were required to accelerate the development and deployment of a national tsunami warning system in FY 2005 and FY 2006. Funds will be used to procure the four remaining Deep-ocean Assessment and Reporting of Tsunamis (DART) buoy spares.

This budget request is necessary to complete the foundation laid by the Administration in FY 2005 and FY 2006 to strengthen the U.S. tsunami warning program.

• NOAA's Environmental Real Time Observation Network (NERON) (formerly known as Cooperative Observer Network Modernization). NOAA is requesting no change to the $4,234,000 base for NERON, which will provide the U.S. with a network of accurate, real-time surface weather data (temperature and precipitation at a minimum) obtained with state-of-the-art measurement, monitoring, and communication equipment. Quality controlled, higher density, real-time surface data will preserve and enhance the climate record of the Nation and improve temperature forecast skill, river height forecast error, radar estimates of precipitation, drought monitoring resolution, hydrology planning, and energy optimization for NWS customers. A specific goal of NERON is to form the infrastructure for the National Integrated Drought Information System (NIDIS). Additional sensors from proven commercial off-the-shelf technology, including wind data, can provide timely data for response to homeland security events or disasters. The objective of NERON is to deploy, integrate or upgrade up to 8,000 modernized sites. A part of NERON is the Historical Climate Network (HCN), comprised of approximately 1200 stations. Because of its unique purpose as the long-term network developed to assist in the detection of regional climate change, it is a high priority of NWS to ensure 5-6 times the integrity of its long-term database. Like other manual NERON sites, the HCN uses older technology, and the data are not available in real-time. Real-time observations are necessary to meet users' needs and to provide sensor information for prompt maintenance actions. The modernization of HCN sites will mitigate the lack of information from geographical sub-regions and provide, in real-time, very high quality surface observations of temperature and precipitation that meets climate, hydrology, and weather and water forecasting needs. Modernizing the HCN will reduce the uncertainty in the measure of regional climate change.

<u>NOAA Weather Radio</u>

NOAA requests no change to the $5,594,000 base to complete and to sustain NOAA Weather Radio (NWR). Funds will be used to procure all of the transmitters for the seventeen (17) sites identified as high risk of severe weather events and begin installations. Nine (9) transmitters are planned to be installed in FY 2006 and the remaining eight (8) in FY 2007. Additionally, funds will be used to begin the refurbishment of four hundred (400) stations established in the 1970s, eliminating single points of failure and improving network reliability.

<u>Weather and Climate Supercomputing</u>

NOAA requests no change to the $19,092,000 base for Weather and Climate Supercomputing. The cyclical upgrade of the NWS weather and climate supercomputing capability is intended to procure the computing and communications equipment needed to receive and process the increasing wealth of environmental data acquired by modernized observing systems, process improved and more sophisticated numerical weather prediction models, and stay current with the supercomputing technology the market has to offer. Execution of this program promotes public safety and the protection of property by providing the National Center for Environmental Protection (NCEP) with the computer systems that are capable of producing more accurate NWS climate and numerical weather prediction (NWP)

guidance products for hurricanes, severe thunderstorms, floods, and winter storms. Additionally, the supercomputing system more accurately forecasts large-scale weather patterns in the medium (3 to 10 days) and extended range (30 days), plus forecasts of major climate events such as El Niño and La Niña. In addition, the computer upgrades will improve the delivery of products to the field and provide system users with enhanced productivity. These products and services will lead to significant economic benefits for users, like the agriculture, construction, and transportation industries.

Weather and Climate Supercomputing Backup

NOAA requests no change to the $7,077,000 base for the Weather and Climate Supercomputing Backup. Because of the critical need of the weather and climate output, it is essential that a backup capability be operational, as part of contingency planning.

Automated Surface Observing System

NOAA requests a decrease of $700,000 and 0 FTE for a total of $3,935,000 for the Automated Surface Observing System (ASOS). This decrease reflects a planned change in the implementation strategy for 240 of the total 377 sites from 40,000 foot ceilometers to 25,000 foot ceilometers.

Advanced Weather Interactive Processing System

NOAA requests no change to the $12,764,000 base for the Advanced Weather Interactive Processing System (AWIPS)/NOAAPort. AWIPS is the cornerstone of the modernized NWS. This system integrates and displays all hydrometeorological data at NWS field offices. AWIPS acquires and processes data from modernized sensors and local sources, provides computational and display functions at operational sites, provides robust communications system to interconnect NWS operational sites, and disseminates warnings and forecasts in a rapid, highly reliable manner. This system integrates satellite, NEXRAD Doppler weather radar data, and numerical weather prediction data enabling field forecasters to better visualize environmental processes to enable the creation of timely and accurate forecasts and warnings. AWIPS provides the only display for NEXRAD Doppler weather radar data at NWS Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs). The AWIPS NOAA-Port satellite broadcast network offers the communications capability to provide internal and external users with open access to much of NOAA's real-time environmental data. These funding resources will be used to further improve AWIPS processing, communications, and software architecture to support system processing demands from increases in NEXRAD Doppler weather radar data, increases in NCEP model data, and new NESDIS polar and geostationary satellite imagery. These pre-planned and ongoing NOAA investments in modeling, satellite instruments, and radar improvements (NEXRAD Product Improvement) represent NOAA's commitment to bring forecasters the data and information required to improve forecast accuracy and warning lead times. NWS Government Performance and Results Act goals are based on the effective use of these technology investments along with advanced decision assistance tools, forecast preparation and advanced database capabilities. Sustained investment in the AWIPS hardware, communications, and software infrastructure is necessary to achieve these performance goals to further improve NWS Tornado Warning Lead Time, Flash Flood Warning Lead Time and Winter Storm Warning Lead Times. These cyclic replacements occur every three years to ensure that NWS stays abreast of technological changes.

Next Generation Weather Radar

NOAA requests no change to the $8,376,000 base for the Next Generation Weather Radar (NEXRAD). NEXRAD is a Doppler weather radar system that provides automated signal processing, computerized processing of data by sophisticated meteorological software algorithms, and a high-capacity, processor-driven communications capability. The system is modular in design, upgradeable, has a long life-cycle expectancy, and provides both government and commercial sector weather users with a wide array of automated weather information that will increase their capability to meet their respective operational requirements. For the NWS, the system uses Doppler technology and hydrometeorological processing to provide significant increases, both in the functional capability and in performance, compared with previous radars, including improved tornado and thunderstorm warnings, increased air safety, improved flash flood warnings, and improved water resources management.

NWS Telecommunication Gateway

NOAA requests no change to the $495,000 for the NWS Telecommunications Gateway (NWSTG) Legacy Replacement. The NWSTG is the NWS communications hub for collecting and distributing weather information to its field units and external users. Replacing the NWSTG system with up-to-date technology will reduce the current delays in collecting and disseminating data by reducing transit time through the NWSTG. The replacement will ensure reliable delivery of NWS products to users and will fully capitalize on better observation data and prediction models to improve services. In FY 2006, NWS will conclude a three-year effort to replace the National Weather Service Telecommunications Gateway (NWSTG) switching system and repair and upgrade NWSTG facilities. In FY 2007, NWS will execute limited technical refresh in the second quarter, and implement

NWS Back-up Telecommunications Gateway (BTG) infrastructure.

Radiosonde Network Replacement

NOAA requests a planned decrease of $333,000 and 0 FTE for a FY 2007 total of $4,014,000 for the Radiosonde Replacement Program. This decrease reflects extending the deployment schedule by one year so that the network is complete in FY 2009.

CONSTRUCTION

NOAA requests an increase of $11,000,000 and 0 FTE for a total of $19,305,000 to prepare the NOAA Center for Weather and Climate Prediction (NCWCP) for FY 2008 occupancy and operations. This FY 2007 increase is consistent with the planned NCWCP investment profile to implement mission critical systems overlap during the transition/move from the current World Weather Building (WWB) to the NCWCP. NOAA must be ready to install systems and equipment during the six-month period prior to the delivery of space, and in the months immediately preceding the phased completion of construction. Lastly, the funding will be used for project management tasks supporting technical oversight of the construction, occupancy, and mission critical systems relocation processes. Also, detailed planning and closely coordinated relocation activities are an absolute requirement to ensure that critical data products are not interrupted during the relocation of 24x7 mission critical systems. This project is a key component of the NWS' effort to improve its weather and climate modeling performance, to accelerate the transfer of newly developed scientific information into operations, and to improve the use of global environmental satellite data. NWS has demonstrated a direct linkage between establishing new facilities in the proximity of research organizations, and improved program performance. The expiration of the WWB lease dictates the timing of the NCWCP Project and affords an outstanding opportunity to enhance the NWS efforts to protect the continuity and flow of critical weather warning, forecasts and data products to the Public. The award of the lease by GSA in September 2005, will ensure occupancy of the new facility in October 2008. FY 2005 funding provided project management for NOAA, and allowed NOAA to initiate the planning and engineering required to support the mission systems relocation. In FY 2007, construction of the NCWCP will be completed. Simultaneously, NOAA will implement procurements to complete all tenant improvements and outfitting such as, but not limited to: telecommunications cabling (systems acquisition and installation); interior design, system furniture acquisition and installation; and relocation costs. The FY 2007 effort will also involve the one-time relocation of mission critical operational systems from the WWB to the NCWCP. This critical system relocation funding will ensure that NOAA will be able to operate its "mission critical" programs by providing an overlap in system functionality during the physical relocation from the WWB to the NCWCP. Funding for project management includes a project manager, space planner, a project engineer and technical support, to provide continued coordination and oversight among all involved parties including GSA, users, contractors, and consultants.

• NOAA requests a planned decrease of $1,000,000 and 0 FTE for a total of $12,504,000 to reflect the transfer of $1,000,000 of Weather Forecast Office (WFO) construction funding to NOAA facilities to support NOAA facility planning requirements. Planned relocation (construction) of the Office of Atmospheric Research (OAR) housing currently collected at the WSO Bairow, will be deferred to FY 2008. This is a one time deferral. Construction elements currently ongoing include the upgrade and modernization of Alaska and Pacific Region Weather Service Offices, Tsunami Warning Centers, and associated employee housing units; upgrades of Heating, Ventilation, and Air Conduction (HVAC) systems at approximately 60 WFOs, uninterrupted power supply (UPS) replacements, and mitigations of all building and fire code violations. This construction effort is essential to bring the NWS into full compliance with federal law and national and local building codes.

ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICES

Proposed funding for FY 2007 includes a decrease in the Polar-Orbiting Satellite Program (POES) of $(11.8) million, a net increase in the Geostationary Satellite Program (GOES) of $112.4 million, and an increase in the National Polar-Orbiting Operational Environmental Satellite Systems (NPOESS) of $20.2 million. These changes allow for continuation of procurements to provide the spacecraft and instruments, launch services, and ground systems necessary to assure continuity of environmental satellite coverage. The budget request will maintain a system of polar-orbiting satellites that obtains global data and a system of geostationary satellites that provides near-continuous observations of the Earth's western hemisphere.

Funding for the POES program is decreasing as it approaches the end of its production cycle with one remaining satellite, NOAA N prime, to be launched. The GOES request includes a decrease of $8.8 million for the GOES-N series of satellites, and an increase of $113.4 million for the next generation GOES-R series. The FY 2007 GOES-R funding will begin engineering for several key instruments and continue the imager production begun in FY 2005. Another $20.2 million in funding is included for

NOAA's share of the NPOESS program - the converged NOAA and Department of Defense (DOD) polar-orbiting system that will replace the current NOAA series and the DOD Defense Meteorological Satellite Program (DMSP).

A total of $97.7 million is included in the budget request to maintain basic mission satellite services including maintenance and operation of satellite ground facilities; provision of satellite-derived products, including hazards support; and conduct of research to improve the use of satellite data..

Included in the above request is $3.8 million to continue the Ocean Remote Sensing Program, which began in FY 1995. During the next several years, NOAA will acquire data from foreign and other non-NOAA satellites that will provide measurement of ocean currents, surface winds and waves, subsurface temperature and salinity profiles, ice thickness and flows, and other marine factors.

Included in the budget request is $51.9M for the NOAA Data Centers and Information Services subactivity base operating funds.

NOAA OCEAN SERVICE (NOS).

NOS operational oceanographic observing systems are designed to measure both oceanographic and meteorological parameters in order to meet user and partner requirements. As a result, users of the data and information support a broad cross-cut of the marine transportation sector, the climate change research sector, weather and water programs, and ecosystems research community.

Funding provided through the FY 2007 budget will allow the continuation of the second generation of the NOS CO-OPS advanced data quality control program, the Continuous Operational Real-time Monitoring System (CORMS AI), as well as the continued implementation of the Ocean Systems Test and Evaluation Program (OSTEP), which is a development program for bringing new sensor technology into operations. The FY 2006 budget has allowed for sufficient support to operate the National Water Level Observation Network (NWLON) and for continued growth of the Physical Oceanographic Real-Time System (PORTS). Both the NWLON and PORTS programs have subsets of operational water level stations with meteorological sensors installed for various partners and users, including the NWS.

Under the NOAA-Wide Coastal Storms Program (CSP), targeted stations of existing federal and state tide station networks have been funded to be enhanced with new meteorological sensors. Under a NOAA Ocean Service Partnership Proposal, first funded in FY 2002, a subset of the NWLON in the Great Lakes was enhanced with new meteorological sensors and with continuous GPS. Previously, special, water level stations were enhanced with meteorological sensors in the Gulf of Mexico with funding from the NWS Southern Region. In FY 2005, NOS is using some of the IOOS funding to upgrade and enhance the NWLON and continues to work cooperatively with the NWS National Data Buoy Center to establish common collection and quality control procedures and data streams for meteorological and water level data from NOS and NDBC observing systems. Hurricane Katrina supplemental funds are being used to harden existing NWLON stations to withstand storm surge and to equip more stations with meteorological sensors. NOS operational nowcast/forecast modeling activities are expanding and rely upon NWS Eta model data streams as hydrodynamic model drivers. NOS, in cooperation with NWS and OAR in have developed an operational nowcast/forecast capability for the Great Lakes.

OFFICE OF ATMOSPHERIC RESEARCH (OAR).

Requested funding for FY 2007 for Weather and Air Quality Research (W&AQR) is $41.2 million--a decrease of $26.6 million or more than 39 percent from the FY 2006 appropriation. Increases consist of upward base adjustments of $1.5 million to partially cover inflationary cost increases plus a critical $2.4 million program increase for Regional Air Quality Assessments and rent increases stemming from the move to the new National Weather Center facility in Norman, OK. Proposed decreases include $4.3 million from the Weather & Air Quality Research Laboratories and Cooperative Institutes line item ($1.3 million of one-time hurricane supplemental funding and $3.0 million as the W&AQR share of the new NOAA Joint Institute for the Northern Gulf of Mexico) as well as $1.0 million from Weather & Air Quality Research Programs (Phased-Array Radar or PAR). The latter decrease actually leaves PAR funding at a level of $3.0 million or $2.0 million higher than the President requested in FY 2006. In addition, terminations totaling $25.3 million are proposed for: Atmospheric Investigation Regional Modeling Analysis and Prediction (AIRMAP) ($4.9 million); New England Air Quality Study ($3.0 million); Targeted Wind Sensing ($2.0 million); Risk Reduction in Water Forecasts at Mississippi State University ($2.0 million), New England Center for the Study of Atmospheric Sciences & Policy ($1.5 million); the "STORM" Program at the University of Northern Iowa ($0.6 million); Remote Sensing Research at the Idaho State University/Boise Center Aerospace Laboratory ($0.5 million); East Tennessee Ozone Study ($0.3 million); Central California Air Quality Study ($0.4 million), Urbanet ($5.9 million), Great Plains Center of Atmosphere and Human Health ($1.0 million), High-

Altitude Air Study ($0.3 million), Reducing Wind-Induced Damages from Storms ($1.0 million), and Coordinate NASA-NOAA Severe Storm R&D ($2.0 million).

NATIONAL POLAR-ORBITING OPERATIONAL ENVIRONMENTAL SATELLITE SYSTEM (NPOESS).

The FY 2007 DOC/DOD budget request for NPOESS is $662.6 million. FY 2007 funds will be used for the continued development of system architecture, technology development efforts, and critical sensor and algorithm development. NPOESS is planned to be launched in FY 2013. This system will exploit advanced hardware and software technologies to produce a more reliable, longer-lived spacecraft with greater mission capability. In addition to new products, NPOESS will also provide a significant reduction (90 minutes to 30 minutes) in the time required to move from sensed to processed data.

NOAA MARINE AND AVIATION OPERATIONS (NMAO).

NMAO supports meteorological activities by collection of related data from ships and aircraft. The FY 2007 President's Budget does not include any significant increases or decreases from the FY 2006 appropriation for NMAO that are related to meteorological data collection.

DEPARTMENT OF DEFENSE (DOD)

The DOD total budget request for FY 2007, excluding NPOESS funding, is $603.4 million which represents a funding increase of 2.1 percent from FY 2006. Specific highlights for each of the military departments are described below:

U.S. AIR FORCE

United States Air Force (USAF) resources for meteorological support fall into several categories: general operations, investment and research, Defense Meteorological Satellite Program (DMSP), and National Polar-orbiting Operational Environmental Satellite System (NPOESS) supporting research. The total Air Force operations and investment funding for FY 2007, including DMSP and NPOESS, is $805 million.

General Operations

The operations portion of Air Force Weather's FY 2007 budget is $317.1 million and funds day-to-day environmental support to the DOD, including the active and reserve components of the Air Force and Army, nine unified commands, and other agencies as directed by the Chief of Staff of the Air Force. Just over 4,400 Active and Reserve Component military and civilian personnel conduct these activities at more than 290 locations worldwide. Approximately 85 percent of personnel specialize in weather; the remainder includes communications, computer, administrative, and logistics specialists.

General Supporting Research

Air Force Weather's FY 2007 budget request for supporting research is $34.9 million. The increase in funding over FY 2006 is a result of research and development efforts related to NPOESS and other transformational initiatives that recapitalize legacy systems, build robust environmental digital data bases and disseminate data streams to DOD and coalition C2 systems in a Machine-to-Machine (M2M)/net-centric era. As part of AF Smart Operations 21st Century (AFSO 21), Air Force Weather is investing in modernized environmental prediction technologies and global information grid technologies that enhance automation and save manpower. Air Force Weather continues their extensive initiative to buildup the strategic center's information technology infrastructure for the expected 10-fold increase in satellite data. Also, Air Force Weather is investing in the following innovative software/systems development efforts in FY 2007 and beyond: Joint Environmental Toolkit (JET), Weather Data Analysis (WDA) and Ensemble Prediction System (EPS). The goals of JET, WDA and EPA are to simplify, standardize, minimize, and automate weather operations at the operational and tactical levels. Specifically, JET will eliminate redundancies/inefficiencies and ultimately extend, consolidate and/or replace the Operational Weather Squadron (OWS) Production System-Phase II (OPS II), the Joint Weather Impacts System (JWIS), the New-Tactical Forecast System (N-TFS), and the weather effects decision aids portion of the Integrated Meteorological System (IMETS). WDA will provide many of the behind the scene tools at the weather production centers necessary for enabling JET to provide decision quality products and information to warfighters. EPS will provide the foundation to fundamentally change legacy forecast processes to an AFSO 21 compatible process necessary for the rapidly changing, net-centric, machine-to-machine future environment. While JET, WDA and EPS work synergistically to provide warfighters a quantum leap in capability, JET is the most visible piece to decision-makers. JET will exploit data contained in the Virtual Joint Meteorological Oceanographic (METOC) Database (VJMDB) via common-user-communications, integrate with joint and coalition command and control and mission planning systems, and provide the machine-to-machine data exchange for assimilating METOC and C4ISR data to meet operational and tactical mission planning and execution requirements. The JET contract was awarded to Raytheon on 28 Mar 20, after a 20-month source selection process.

DMSP

DMSP operations are a critical

source of space-borne meteorological data for the military services and other high-priority DOD programs. DMSP environmental data is also distributed to the National Weather Service (NWS), National Environmental Satellite, Data, and Information Service (NESDIS), the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC), the Naval Oceanographic Office (NAVOCEANO), and Air Force Weather Agency (AFWA) according to interagency agreements.

The Air Force's total projected FY 2007 outlays for DMSP are $104.8 million. This funding provides for the operations and sustainment of the on-orbit constellation, as well as integration, test, and flight hardware modifications and replacement to maximize performance and longevity of the satellites that remain to be launched. DMSP satellites are acquired and launched by the Air Force and funding to operate the satellites on-orbit is transferred by the Air Force to NOAA each year.

NPOESS Supporting Research

The FY 2007 DOD R&D budget for NPOESS is $349.3 million for the continued development of system architecture, technology, critical sensors, and algorithms. These dollars are applied to both the NPOESS Preparatory Project (NPP) run by NASA and the NPOESS program being which is being acquired by a tn-agency Integrated Program Office. The NPOESS program is currently in a Nunn-McCurdy breach and is going through a certification process being led by OSD/AT&L. A decision on a restructured NPOESS program will be provided to Congress.

U.S. NAVY

The U.S. Navy FY 2007 budget request for meteorological programs is $90.4 million. The request includes $47.8 million for operational programs and $42.6 million for supporting research.

The Naval Oceanography Program (NOP) remains a unique, world-class program. Focusing support in the environmentally complex coastal/littoral regions around the globe, Naval Meteorology and Oceanography (METOC) personnel (Navy and Marine Corps) are required to provide intelligence preparation of the environment (IPE) for operational decision-makers by assessing the impact of atmospheric and ocean phenomena on platforms, sensors and weapon systems. Additionally, Navy and Marine Corps METOC personnel provide for safe flight and navigation in support of naval, joint, and combined forces operating throughout the world's oceans. This is done with a cadre of highly trained military and civilian personnel, educated in both the sciences and warfighting applications. By teaming with, and leveraging the efforts of other agencies and activities, the NOP meets these challenges in a most cost-effective manner, providing a full spectrum of products and services with only a small percentage of the Federal weather budget.

The Naval Oceanography Program is required to provide comprehensive and integrated weather and ocean support worldwide. The Oceanographer/Navigator of the Navy sponsors programs in four closely related disciplines - meteorology, oceanography, geospatial information services, and precise time and astrometry. All are used to protect ships, aircraft, fighting forces, and shore establishments from adverse ocean and weather conditions, and to provide a decisive tactical or strategic edge by exploiting the physical environment to optimize the performance and efficiency of platforms, sensors, and weapons.

Owing to the crucial interrelationship of the ocean and the atmosphere, Naval METOC requires various oceanographic products to provide the requisite meteorological services. In addition to aviation and maritime METOC support, Navy and Marine Corps METOC teams provide a variety of unique services on demand, such as electro-optical, electro-magnetic and acoustic propagation models and products, METOC-sensitive tactical decision aids, and global sea ice analyses and forecasts.

Support to naval operations is provided under the direction of the Commander, Naval Meteorology and Oceanography Command (CNMOC) located at the Stennis Space Center, Mississippi and the Marine Corps advocate for METOC, the Deputy Commandant for Aviation, at Headquarters Marine Corps, Washington, DC. Naval METOC support starts with sensing the battlespace physical environment and culminates with weapons arriving on target and enabling personnel to operate in the battlespace without being adversely affected by physical environmental phenomena. Operational support for the Navy and Marine Corps includes the day-to-day provision of meteorological and oceanographic (METOC) products and services. As naval operations in the littoral increase, Naval METOC support is directed towards providing on-scene capabilities to personnel that directly furnish environmental data for sensor, weapon system, and personnel planning and employment. These on-scene capabilities are key elements for enabling the warfighters to take advantage of the natural environment as part of battlespace management.

Naval METOC systems acquisition is accomplished through the Program Executive Office for Command, Control, Communications, Computers and Intelligence and Space (C41 and Space) in San Diego, California.

Naval METOC Research and Development (R&D) are cooperatively sponsored by the Oceanographer/Navigator of the Navy and the Chief of Naval Research. Naval R&D efforts typically have applications to meteorologi-

cal, oceanographic, and/or tactical systems. Navy's tabulation of budget data includes R&D funding for basic research, applied research, demonstration and validation, and engineering and manufacturing development.

Projects initiated by the Navy and Marine Corps, under sponsorship of the Oceanographer/Navigator of the Navy, transition from engineering development to operational naval systems. Such efforts include advances in Naval METOC forecasting capabilities, enhancements to communications and data compression techniques, further development and improvement of models to better predict METOC parameters in littoral regions, and an improved understanding of the impact these parameters have on sensors, weapon systems, and platform performance.

As the Department of the Navy continues a transformation begun under *SEAPOWER 21*, increased emphasis will be placed on making the Navy combat-ready, forward-deployed, rotational, and surge-capable to contribute to combined and joint operations in an era of shifting global threats and challenges. The CNMOC Organization is also currently transforming for efficiency and effectiveness to meet these future requirements. The Naval METOC Community continues to work closely with research developers and operational forces to ensure that naval and joint force commanders will always have the most accurate, timely, and geo-referenced METOC information available for successful operations.

U.S. ARMY

The U.S. Army estimates a requirement for $45.3 million for operational support and $10.9 million in research and development in FY 2007. The total amount of money budgeted for weather support is estimated because the costs to support U.S. Air Force (USAF) Battlefield Weather forces are normally part of the overall G-3 or G-2 operating budget at the Army Commands (ACOMs), Army Service Component Commands (ASCCs), Corps, Division, or Brigade level and are not assigned their own program element or budget line. Additionally, programs or projects that are assigned a budget line are often part of a larger project's budget (e.g., IMETS as part of DCGS-A) and the exact amount of monies spent on meteorological related activities cannot be verified. The budget numbers presented in this report represent the best estimate of the Army on meteorological related spending over the period of the report. Operational support is projected to decrease approximately $5.9 million over FY 2006 expenditures and research is estimated to decrease about $2.4 million from the previous year. Staffing will increase slightly. Decreases in funding for meteorological related activities were fairly evenly spread across all activities for FY 2007. Increases in staffing are a result of a projected increase in ARTYMET units within FORSCOM.

Army monies for meteorology are spent in four main areas: support to U.S. Army Artillery Met Sections (ARTYMET), support to USAF Battlefield Weather forces at Army locations, research and development related to the Army mission, and the development, production, and maintenance of Army meteorological systems.

ASCCs with Staff Weather Officers and their associated Battlefield Weather forces provide the same support and services to Air Force Weather (AFW) personnel that they normally provide to Army personnel. This support includes the use of facilities to house weather operations, medical support, access to training facilities, office supplies, utilities and maintenance for weather facilities, vehicles and tactical equipment, and funding for official travel. Eighth U.S. Army, U.S. Army Europe, U.S. Army Pacific, Forces Command, and Training and Doctrine Command all provide this support to AFW personnel assigned at the ACOM level and below. The departure of the First Infantry Division from United States Army Europe significantly reduced the amount of weather support required in USAREUR and resulted in a projected fifty percent decrease in weather related expenditures within that ASCC for FY 2007. USARPAC weather expenditures increased for FY 2007 due to projected increases in maintenance and operating budgets.

Major portions of MACOM meteorological budgets go to support Artillery Meteorology Sections, also known as ARTYMET Teams, or Met Sections. Wind data are then passed to the U.S. Army Artillery units for firing computations. Artillery Met Sections range in size from six personnel at a Light Division, to twelve personnel at a Heavy Division. Eighth U. S. Army, U.S. Army Europe, U.S. Army Pacific, Forces Command, and the Army National Guard all support Met Sections. Training and Doctrine Command supports twenty-four military and civilian personnel at the U.S. Army Artillery School at Fort Sill, Oklahoma. These personnel train ARTYMET Teams on the use of the AN/TMQ-41 Meteorological Measuring Set. ARTYMET team structures will be changing over the next few years to support the Army's new modularity concept. FORSCOM is already making these changes to its artillery sections, and other MACOMS will follow as their forces transform to the new units of action. No attempt has been made to convert the part time Army National Guard ARTYMET Teams into full time equivalents.

Space and Missile Defense Command (SMDC) supports several meteorological missions. SMDC has funding designated for the operational support at the High Energy Laser Systems

Test Facility (HELSTF) for contract services to operate and maintain the instrumentation, equipment, and facilities to support the atmospheric sciences/meteorological mission. SMDC also operates contract support services to operate the Ronald Reagan Missile Defense Test Site for operations support and special weather programs.

Headquarters, Department of the Army, Deputy Chief of Staff, G-2 employs two full-time meteorologists for:

- Development of meteorological policy;
- Coordination of meteorological support within the Department of the Army and with other Department of Defense and Federal agencies and organizations;
- Development of Department of the Army Policy concerning weather; environmental services, and oceanographic support to the Army (less those environmental services functions assigned to the Corps of Engineers); and
- Development of Department of the Army policy concerning peacetime weather support.

This office also sponsors a company grade Army liaison officer at the Air Force Weather Agency (AFWA) in Omaha, Nebraska, to serve in a consulting role to AFWA. The AFWA position is currently vacant. The Air Force provides one full time Staff Weather Officer to serve as a liaison between AFW and the Army Staff.

Forces Command (FORSCOM) will program approximately $13.9 million in FY 2007 for meteorological operations support. Of the $13.9 million budgeted, $13.6 million will be used in support of FORSCOM ARTYMET operations and $0.3 million will be spent for supplies, travel and other contracts for Air Force weather teams supporting FORSCOM units. This includes the addition of a new weather unit at Fort Riley to support the 1st Infantry Division.

Training and Doctrine Command (TRADOC) has programmed approximately $4.2M for FY 2006 for meteorological services. The majority of these TRADOC funds, a total of $4.OM, were programmed for operations support related to training development, instructor/support personnel, logistics (expendable supplies), and repair costs on artillery meteorological systems at the US Army Field Artillery School (USAFAS). Training development costs ($l.74M) in FY 2006 are a result of initiatives to develop interactive multi-media instructional products and cost associated with rewrite of the artillery meteorology field manual. In FY 2007, these costs are projected to decrease to $1 .06M as new instructional material and the field manual are delivered. Instructor/Support personnel costs ($1 .85M) in FY 2006 are the result of USAFAS at Fort Sill, OK employing 28 personnel to conduct training using the AN/TMQ-41 Meteorological Measuring Set (MMS) and the AN/TMQ-52 Meteorological Measuring Set-Profiler (MMS-P). Personnel funding is expected to decrease by approximately $142K in FY 2007 due to the elimination of two contracted instructor positions. Logistics/supply costs ($141K) in FY 2006 funds supplies for meteorological sounding equipment to support live fire and training at Fort Sill. These costs increased significantly from FY 2005 expenditures ($99K) as a result of implementing the new Modular Force design for Army Artillery Meteorology. Under the modular design, the number of Army Artillery Meteorology Sections increases from 82 individual sections to 122 individual sections. In FY 2007 supply costs are expected to be approximately $151K. Repair costs ($260K) in FY 2006 on artillery meteorological systems are expected to decrease by approximately $30K in FY 2007 due to a reduction in the number of MMS-Profiler Systems that will be available for training at USAFAS.

TRADOC also programmed $66K in FY 2006 to fund a TRADOC Systems Manager (TSM) position for the Army's Integrated Meteorological System (IMETS). This position falls under the TRADOC Program Integration Office - All Source Analysis System (TPIO-ASAS) at the US Army Intelligence Center and School (USAICS) at Ft Huachuca, AZ. TPIO-ASAS has programmed $69K for this same position in FY 2007. TRADOC transferred $122K to Air Combat Command for the maintenance and service of five Automated Surface Observing Sensor (ASOS) systems and two pole-mounted Tactical Meteorological Observing Systems (TMOS) at Fort Rucker, AL. Maintenance and service costs have been programmed to increase to $126K in FY 2007.

Army Materiel Command (AMC) will fund a variety of activities for FY 2007, most of which fall into research and development and systems acquisition. AMC will fund developmental and testing costs associated with the Integrated Meteorological System (IMETS). The IMETS budget for FY 2005 underwent an $11.9 million reduction to fund higher priority needs within the Army. However, the Distributed Common Ground System - Army (DCGS-A) and the Department of the Army provided $7.7 million and $6.1 million in FY 2006 and FY 2007, respectively, to maintain the capabilities of this program as it transitions into the DCGS-A. Normal program life cycle issues reduced the Artillery's Profiler budget by $2.6 million in FY 2007. One Profiler system is planned for procurement in FY 2007. Other activities within AMC include Army Research Laboratory, Battlefield Environment Division, which will continue to operate an integrated program of both basic and applied research. The Army Research Office will continue basic research activities with a slight reduction in budget for FY 2007; there was a reduction in expenditures on

weather-related research. It is anticipated that FY 2007 funding for weather-related research efforts at U.S. Army Research Institute of Environmental Medicine (USARIEM) will be level relative to the FY 2006 Level.

DEPARTMENT OF HOMELAND SECURITY (DHS)

On March 1, 2004, the Department of Homeland Security (DHS) assumed primary responsibility for ensuring that emergency response professionals are prepared for any situation in the event of a terrorist attack, natural disaster, or other large-scale emergency. This entails providing a coordinated, comprehensive Federal response to any large-scale crisis and mounting a swift and effective recovery effort. DHS will also prioritize the important issue of citizen preparedness, and educating America's families on how best to prepare their homes for a disaster and tips for citizens on how to respond in a crisis will be given special attention at DHS.

U.S. COAST GUARD (USCG).

All of USCG's funding for meteorological programs is for operations support. For FY 2007, the requested funding level is $20.1 million. (The Coast Guard does not have a specific program and budget for meteorology--all meteorological activities are accomplished as part of general operations.)

The Coast Guard's activities include the collection and dissemination of meteorological and iceberg warning information for the benefit of the marine community. The Coast Guard also collects coastal and marine observations from its shore stations and cutters, and transmits these observations daily to the Navy's Fleet Numerical Meteorology and Oceanography Center and NOAA's National Weather Service. These observations are used by both the Navy and NOAA in generating weather forecasts.

The Coast Guard also disseminates a variety of weather forecast products and warnings to the marine community via radio transmissions. Coast Guard shore stations often serve as sites for NWS automated coastal weather stations, and the National Data Buoy Center provides logistics support in deploying and maintaining NOAA offshore weather buoys.

The International Ice Patrol conducts iceberg surveillance operations and provides warnings to mariners on the presence of icebergs in the North Atlantic shipping lanes. Coast Guard efforts in meteorological operations and services have not changed significantly during recent years.

DEPARTMENT OF THE INTERIOR (DOI)

The total DOI/BLM weather funding request for FY 2007 is $2.4 million. This amount is for meteorological operations and the support of the Bureau of Land Management (BLM) Remote Automatic Weather Station (RAWS) program. An additional $1.1 million is recovered each year through reimbursable accounts with participating agencies. Normal operations and maintenance of the RAWS program is approximately $900,000 yearly. (This includes travel, transportation, utilities, services, supplies, equipment and other non-labor costs.)

Support of the RAWS program by the BLM will continue in FY 2007, as part of the Wildland Fire Agencies' participation in Fire Weather activities and the National Fire Danger Rating System (NFDRS). In addition to upgrading and maintaining fixed-site RAWS, the BLM will address increasing demand for the use of mobile units for both fire and non-fire applications. Continued efforts will be made to achieve an optimum balance of fixed and mobile RAWS resources and support. Cooperation between DOI agencies and the USDA Forest Service regarding combined meteorological requirements for the National Wildland Fire support functions is ongoing. Interagency RAWS activity is coordinated at a working group level with representation by all participants, and will continue to implement NFDRS standards to ensure the protection of both life and property from wildland fires.

DEPARTMENT OF TRANSPORTATION (DOT)

The DOT total budget request for FY 2007 is $546.4 million which represents a funding increase of 7.3 percent from FY 2006. The meteorological programs for the Federal Aviation Administration and the Federal Highway Administration, for FY 2007, are described below.

FEDERAL AVIATION ADMINISTRATION (FAA).

For 2007, FAA has requested a total $541.9 million for the Aviation Weather Programs including acquisition of new systems, operations and support, and supporting research. The actual funding for aviation weather in FY 2006 was $504.5 million. The $39.8 million increase in FY 2007 constitutes a 7.4 percent increase in total funding. The changes are comprised of a) increases in acquisitions of $2.0 million to $93 million, as new systems are required to enhance support of field operations and the aviation industry; b)increases in operations and support of $33 million to $419 million, reflecting salary increases throughout the agency, in associated logistics, and changes in the automated flight service station operations as a result of the A-76 contract award; and c)an increase for aviation weather research of $2.1 million to a total of $23.6 million.

The funding changes reflect major initiatives in the aviation weather programs to bring much automation to the collection of weather observations from remote sensors, to the dissemination of weather products, graphics and decision making information available for use by the air traffic facilities, pilots, the aviation industry and gen-

eral aviation users.

The AWRP will continue research into understanding the geophysical phenomenon in the atmosphere and around airports that present hazardous conditions for aircraft operations. Among these are in-flight icing, turbulence, visibility, ceiling, convective activity, tornadoes, etc. Additional work will be done to improve models, develop better graphics for decision making information, and the impacts of space weather.

FEDERAL HIGHWAY ADMINISTRATION (FHWA).

The total FHWA request for surface transportation weather programs in FY 2007 is $4.2 million, all of which will be used for supporting research and special programs.

In 1999, the FHWA began documenting road weather data requirements, which have served as the basis for the majority of work and research in this area. This work, some of which is described below, includes addressing the technical aspects of the road transportation system (including environmental data collection, processing and dissemination) as well as the institutional challenges associated with system implementation.

These institutional challenges encompass coordination within state and local Departments of Transportation (DOTs) as well as across the transportation and meteorological communities. With regard to technical areas of interest, data collection efforts have included increased coverage of atmospheric and road condition observations, as well as incorporation of road weather data (e.g., pavement and subsurface observations) into broader meteorological observation networks. Better processing includes the application of higher resolution weather models and the development of road condition prediction models (e.g., heat balance models) that are needed to develop the appropriate road weather information. This road weather information will enable more effective decision making, leading to a safer and more efficient surface transportation system.

A USDOT initiative entitled *Clarus* will develop, demonstrate and support deployment of a nationwide surface transportation weather observing and forecasting system, and ultimately foster nationwide data sharing capabilities. *Clarus* will allow agencies to share quality-checked environmental data, ultimately improving forecasts and value-added weather information products, as well as supporting anytime, anywhere road weather information for all road and transit users and operators.

A multi-year effort has been undertaken by the FHWA in cooperation with six national laboratories to prototype and field test advanced decision support tools for winter maintenance managers. The Maintenance Decision Support System (MDSS) prototype is a decision support tool that integrates relevant road weather forecasts, coded rules of practice for winter maintenance operations, and maintenance resource data to provide managers with customized road treatment recommendations. The first functional MDSS prototype was demonstrated in Iowa in early 2003, and during winter 2003-2004. During winter 2004-2005, the MDSS prototype was successfully deployed in a third demonstration in Colorado, and in early 2006, this product was declared a "market ready technology." The current focus of the MDSS project is to continue to build on current outreach program activities such as sponsoring annual stakeholder meetings, conducting product "Road Shows," facilitating technology transfers to the private sector, providing assistance to public agencies in writing request for proposals, and participating in informational conferences. The project team also plans to conduct a series of cost/benefit analyses to produce "hard" financial data that can be used to support investing in such a system and exploring the potential of expanding the functionality of MDSS beyond winter maintenance to include such activities as summer maintenance and traffic management.

The FHWA recently completed a study on how Traffic Management Centers (TMCs) around the country integrate road weather information into their operations. The FHWA documented the types of road weather information received by TMCs, the means of information delivery, how information needs change as the severity of a weather event increases, and how that information impacts traffic management decisions. The FHWA is also conducting analyses and developing models to quantify the impacts of various weather events on highway traffic, as well as investigating a variety of weather-responsive traffic management strategies such as changing traffic signal timing in response to weather and posting weather-related messages on variable message signs. These efforts will help FHWA advance the state-of-the-practice in weather-responsive traffic management.

The efforts described above, as well as future activities captured in the Road Weather Management Program plan should be examined within the context of two key reports published in early 2004, and described below.

In 2002, the FHWA asked the National Research Council (NRC) Board of Atmospheric Sciences & Climate to examine what needs to be done from the research, development, and technology transfer perspectives to improve the production and delivery of weather-related information for the nation's roadways. In March 2004, the NRC released a report, *Where the Weather Meets the Road: A Research Agenda for Improving Road Weather Services*, that recommended the creation of a focused, national road weather research program led by

FHWA that brings together the transportation and meteorological communities, identifies research priorities, and implements new scientific and technological advances. NRC recommendations included making better use of existing road weather information and technologies to increase capabilities for transportation research, establishing a nationwide real-time road weather observing system, developing observing capabilities to assess the accuracy of road weather forecasts, improving environmental sensor technologies, and developing new means to effectively communicate road weather information to a wide range of users. Most, if not all of these recommendations, have been incorporated into the roadmap that is being used to guide the activities of the Road Weather Management Program.

To strengthen relationships between the meteorological and surface transportation communities, the FHWA Road Weather Management Program and the American Meteorological Society (AMS) co-sponsored a *Policy Forum on Weather and Highways* in November 2003. The objective was to discuss the provision of weather information to improve highway operations, the development of strategies to effectively respond to weather information, and the policy issues related to effective application of weather services to the management of the nation's highway system. The forum brought together nearly 100 representatives from public, private, and academic sectors at federal, state, and local levels. The report resulting from the forum, *Weather and Highways: Report of a Policy Forum*, contained several recommendations including long-term congressional funding to develop a national road weather research, development, and applications program; close coordination of federal and state DOTs to improve the safety and efficiency of highways during adverse weather; and establishing a national road weather data collection, processing, and dissemination system.

Based upon recommendations in the AMS and NRC reports, the FHWA and the National Oceanic and Atmospheric Administration (NOAA) signed a memorandum of understanding (MOU) in July of 2005, that will enable the two agencies to work together to achieve shared goals for a safer and more efficient surface transportation system. By working together, these two agencies can take advantage of each other's investments and expertise, as well as promote improved surface transportation weather training, products, and services. A near-term goal of the new partnership is the introduction of new products, services and training to improve the application of weather information to surface transportation operations.

FEDERAL RAILROAD ADMINISTRATION (FRA).

In 2007, the FRA has requested a total $289 million to support the Nationwide Differential Global Positioning System (NDGPS). FRA plans to transfer this funding to NOAA in support of their NDGPS efforts.

ENVIRONMENTAL PROTECTION AGENCY (EPA)

All of the EPA's funding of meteorological and air quality programs is for supporting research. The anticipated funding level in FY 2007 for directed meteorological research is $9.0 million which is the same funding level as in FY 2006.

Currently, increased attention is being paid to the effects of airborne toxins and fine particulate matter on human health, on the effect of climate change on air quality, and the impact on ecosystems. In addition, to promote excellence in environmental science and engineering, EPA established a national fellowship program and substantially increased its support for investigator-initiated research grants. The funding for grants (with reliance on quality science and peer review) and for graduate fellowships (to support the education and careers of future scientists) will provide for a more balanced, long-term capital investment in improved environmental research and development. The funding for the grants program will remain about the same in FY 2007 as in FY 2006.

This program will fund research in areas including ecological assessment, air quality, environmental fate and treatment of toxins and hazardous wastes, effects of global climate change on air quality, and exploratory research. The portion of these grants that will be awarded for meteorological research during FY 2007 cannot be foreseen, but it is probable that the grant awards will increase the base amount of $9.0 million listed above for directed meteorological research.

In collaboration with NOAA, EPA is continuing its development and evaluation of air quality models for air pollutants on all temporal and spatial scales as mandated by the Clean Air Act as amended in 1990. Research will focus on urban, mesoscale, regional, and multimedia models, which will be used to develop air pollution control strategies, human and ecosystem exposure assessments, and air quality forecasting. There will be increased emphasis placed on meteorological research into regional and urban formation and transport of air contaminants in support of the revisions to the National Ambient Air Quality Standards and homeland security. Increased efficiency of computation and interpretation of results are being made possible by means of supercomputing and scientific visualization techniques.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

For FY 2007, NASA requests a total of

$168.8 million. The majority of this funding ($166.4 million) is for supporting research.

The meteorology supporting research programs lie within the Earth-Sun System Division of NASA's Science Mission Directorate (SMD). Due to recent organizational changes, the task of extracting meteorology related funds in the SMD budget has become a complicated undertaking. The line items in the Earth-Sun System budget that support Earth Science are Earth Systematic Missions, Earth System Science Pathfinder, Earth-Sun System Multi-Mission Operations, Earth-Sun Research, Applied Sciences, Education and Outreach and Earth-Sun Technology. Estimation of the meteorology share of this budget was a two step process. The Earth Science part of the budget was estimated in the first step and the meteorology share was estimated, in the second step, to be one eighth of this sum.

NUCLEAR REGULATORY COMMISSION (NRC)

The NRC planned expenditure of $120,000 in FY 2007, is for meteorological operations to continue technical assistance for the analysis of atmospheric dispersion for routine and postulated accidental releases from nuclear facilities, and the review of proposed sites for possible construction of new nuclear power plants.

The meteorological support program in the NRC is focused primarily on analyzing and utilizing meteorological data in atmospheric transport and dispersion models. These models provide insight on plume pathways in the near- and far-fields for building wake and dispersion characteristics to perform dose calculations on postulated releases to the environment. Meteorological information is used as input to the probabilistic safety assessment, the assessment of the radiological impacts of routine releases from normal operations, the assessment of other (non-radiological) hazards that may impact safe operation of the facility, and the assessment of design or operational changes proposed for the facility.

Additionally, after a hiatus of some 25 years, the nuclear power industry has expressed an interest in seeking site approvals for new nuclear power plants. Three early site permit applications have been received and are currently under review. These reviews will also consider regional climatology and local meteorology. In addition to its internal review activities, the NRC may seek assistance from other Federal agencies to support its safety reviews.

AGENCY FUNDING BY BUDGET CATEGORY

Table 2.2 depicts how the agencies plan to obligate their funds for meteorological operations broken down by "budget category." The two major categories are "Operations Support" and "Systems Acquisition." To a large degree, these categories correspond to non-hardware costs (Operations Support) and hardware costs (Systems Acquisition). For agency convenience in identifying small components that do not fit into these two major categories, a third category is added called "Special Programs." Programs that provide support to several government agencies such as the Air Force's DMSP are listed on a separate line.

In FY 2007, Operational Costs requested are $3.03 billion with a total of $1.80 billion (59.3 percent) for Operations Support, $1.19 billion (39.3 percent) for Systems Acquisition, and $40 million (1.3 percent) for Special Programs.

Table 2.3 describes how the agencies plan to obligate their funds for meteorological supporting research according to budget categories. The agencies' supporting research budgets are subdivided along similar lines--Research and Development (non-hardware), Systems Development (hardware), and Special Programs (for those items that do not easily fit into the two major categories).

For FY 2007, agencies will obligate a total of $414 million in Supporting Research funds in the following manner: $331.6 million (80.2 percent) to research and development and $82.1 million (19.8 percent) to Systems Development.

AGENCY FUNDING BY SERVICE CATEGORY

Table 2.4 summarizes how the agencies plan to obligate operational funds for basic and specialized meteorological services; Table 2.5 is a similar breakout for supporting research funds.

Table 2.4 reveals the distribution of FY 2007 operational funds: basic meteorology services receiving 59.5 percent; aviation 19.7 percent; marine 4.3 percent; agriculture/forestry 0.7 percent; general military services 15.7 percent; and other specialized services accounting for 0.2 percent. Table 2.5 shows the distribution of supporting research funds among the services with basic meteorology receiving 23.8 percent, aviation 6.1 percent, marine 10.4 percent, agriculture and forestry 7.6 percent, general military 8.7 percent, and the remaining 43.4 percent dedicated to other meteorological services.

The definitions of specialized and basic services are described below:

Basic Services.

Basic services provide products that meet the common needs of all users and include the products needed by the general public in their everyday activities and for the protection of lives and property. "Basic" services include the programs and activities that do not fall under one of the specialized services.

Specialized Meteorological Services.

Aviation Services. Those services and facilities established to meet the requirements of general, commercial, and military aviation.

Marine Services. Those services and facilities established to meet the requirements of the DOC, DOD, and DOT on the high seas, on coastal and inland waters, and for boating activities in coastal and inland waters. The civil programs which are directly related to services solely for marine uses and military programs supporting fleet, amphibious, and sea-borne units (including carrier-based aviation and fleet missile systems) are included.

Agriculture and Forestry Services. Those services and facilities established to meet the requirements of the agricultural industries and Federal, state, and local agencies charged with the protection and maintenance of the nation's forests.

General Military Services. Those services and facilities established to meet the requirements of military user commands and their component elements. Programs and services which are part of basic, aviation, marine, or other specialized services are not included.

Other Specialized Services. Those services and facilities established to meet meteorological requirements that cannot be classified under one of the preceding categories; such as, space operations, urban air pollution, global climate change, and water management.

PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS

Table 2.6 depicts agency staff resources in meteorological operations. The total agency staff resources requested for FY 2007 is 13,505. This total represents a decrease of 13.5 percent from FY 2006, with the largest decreases occurring in Navy and FAA personnel.

TABLE 2.2 AGENCY OPERATIONAL COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

AGENCY	Operations Support FY2006	Operations Support FY2007	Systems Acquisition FY2006	Systems Acquisition FY2007	Special Programs FY2006	Special Programs FY2007	Total FY2006	Total FY2007	Total %CHG	% of FY2007 TOTAL
Agriculture	20201	19710	0	0	0	0	20201	19710	-2.4	0.7
Commerce/NOAA(Subtot)	960993	970329	854058	950915	22981	32965	1838032	1954209	6.3	64.5
NWS	746844	783446	79575	66611	21825	31809	848244	881866	4.0	29.1
NESDIS	177737	149579	774483	884304	0	0	952220	1033883	8.6	34.1
OAR	0	0	0	0	0	0	0	0	0	0.0
NOS	24078	24970	0	0	0	0	24078	24970	3.7	0.8
NMAO	12334	12334	0	0	1156	1156	13490	13490	0.0	0.4
Defense(Subtot)	373349	364632	129583	148513	1051	911	503983	514056	2.0	17.0
Air Force	260324	265329	49077	51760	0	0	309401	317089	2.5	10.5
DMSP*	16946	16196	67175	87689	0	0	84121	103885	23.5	3.4
Navy	58567	47036	721	750	0	0	59288	47786	-19.4	1.6
Army	37512	36071	12610	8314	1051	911	51173	45296	-11.5	1.5
Homeland Security (Subtot)	19340	20110	0	0	0	0	19340	20110	4.0	0.7
USCG	19340	20110	0	0	0	0	19340	20110	4.0	0.7
Interior/BLM	2400	2400	0	0	0	0	2400	2400	0.0	0.1
Transportation(Subtot)	386486	419379	91107	93110	5723	6135	483316	518624	7.3	17.1
FAA	386197	419090	91107	93110	5723	6135	483027	518335	7.3	17.1
FRA	289	289	0	0	0	0	289	289	0.0	0.0
FHWA	0	0	0	0	0	0	0	0	0.0	0.0
EPA	0	0	0	0	0	0	0	0	0.0	0.0
NASA	2114	2423	280	40	0	0	2394	2463	2.9	0.1
NRC	120	120	0	0	0	0	120	120	0.0	0.0
TOTAL	1765003	1799103	1075028	1192578	29755	40011	2869786	3031692	5.6	100.0
% of FY TOTAL	61.5%	59.3%	37.5%	39.3%	1.0%	1.3%	100.0%	100.0%		

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

TABLE 2.3 AGENCY SUPPORTING RESEARCH COSTS, BY BUDGET CATEGORY

(Thousands of Dollars)

AGENCY	Research & Development FY2006	Research & Development FY2007	Systems Development FY2006	Systems Development FY2007	Special Programs FY2006	Special Programs FY2007	Total FY2006	Total FY2007	Total %CHG	% of FY2007 TOTAL
Agriculture	39706	31395	0	0	0	0	39706	31395	-20.9	7.6
Commerce/NOAA(Subtot)	118504	85467	4320	4320	0	0	122824	89787	-26.9	21.7
NWS	19107	20180	1950	1950	0	0	21057	22130	5.1	5.3
NESDIS	31753	24771	0	0	0	0	31753	24771	-22.0	6.0
OAR	66488	39360	1870	1870	0	0	68358	41230	-39.7	10.0
NOS	0	0	500	500	0	0	500	500	0.0	0.1
NMAO	1156	1156	0	0	0	0	1156	1156	0.0	0.3
Defense(Subtot)	69630	67575	17590	21794	0	0	87220	89369	2.5	21.6
Air Force	14937	14074	13738	20825	0	0	28675	34899	21.7	8.4
DMSP*	0	0	3852	969	0	0	3852	969	-74.8	0.2
Navy	41427	42581	0	0	0	0	41427	42581	2.8	10.3
Army	13266	10920	0	0	0	0	13266	10920	-17.7	2.6
Homeland Security (Subtot)	0	0	0	0	0	0	0	0	0.0	0.0
USCG	0	0	0	0	0	0	0	0	0.0	0.0
Interior/BLM	0	0	0	0	0	0	0	0	0.0	0.0
Transportation(Subtot)	25706	27800	0	0	0	0	25706	27800	8.1	6.7
FAA	21506	23600	0	0	0	0	21506	23600	9.7	5.7
FRA	0	0	0	0	0	0	0	0	0.0	0.0
FHWA	4200	4200	0	0	0	0	4200	4200	0.0	1.0
EPA	9000	9000	0	0	0	0	9000	9000	0.0	2.2
NASA	108700	110400	54100	56000	0	0	162800	166400	2.2	40.2
NRC	0	0	0	0	0	0	0	0	0.0	0.0
TOTAL	371246	331637	76010	82114	0	0	447256	413751	-7.5	100.0
% of FY TOTAL	83.0%	80.2%	17.0%	19.8%	0.0%	0.0%	100.0%	100.0%		

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

TABLE 2.4 AGENCY OPERATIONAL COSTS, BY SERVICE

(Thousands of Dollars)

AGENCY	Basic Meteorology FY2006	Basic Meteorology FY2007	Aviation FY2006	Aviation FY2007	Marine FY2006	Marine FY2007	Agriculture & Forestry FY2006	Agriculture & Forestry FY2007	General Military FY2006	General Military FY2007	Other FY2006	Other FY2007	Total FY2006	Total FY2007
Agriculture	0	0	0	0	0	0	20201	19710	0	0	0	0	20201	19710
Commerce/NOAA(Subtot)	1683335	1794508	63700	63700	90997	96001	0	0	0	0	0	0	1838032	1954209
NWS	717625	747135	63700	63700	66919	71031	0	0	0	0	0	0	848244	881866
NESDIS	952220	1033883	0	0	0	0	0	0	0	0	0	0	952220	1033883
OAR	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOS	0	0	0	0	24078	24970	0	0	0	0	0	0	24078	24970
NMAO	13490	13490	0	0	0	0	0	0	0	0	0	0	13490	13490
Defense(Subtot)	10078	8124	17786	14336	17193	13858	0	0	455960	475349	2966	2389	503983	514056
Air Force	0	0	0	0	0	0	0	0	309401	317089	0	0	309401	317089
DMSP*	0	0	0	0	0	0	0	0	84121	103885	0	0	84121	103885
Navy	10078	8124	17786	14336	17193	13858	0	0	11265	9079	2966	2389	59288	47786
Army	0	0	0	0	0	0	0	0	51173	45296	0	0	51173	45296
Homeland Security (Subtot)	0	0	0	0	19340	20110	0	0	0	0	0	0	19340	20110
USCG	0	0	0	0	19340	20110	0	0	0	0	0	0	19340	20110
Interior/BLM	0	0	0	0	0	0	2400	2400	0	0	0	0	2400	2400
Transportation(Subtot)	0	0	483027	518335	0	0	0	0	0	0	289	289	483316	518624
FAA	0	0	483027	518335	0	0	0	0	0	0	0	0	483027	518335
FRA	0	0	0	0	0	0	0	0	0	0	289	289	289	289
FHWA	0	0	0	0	0	0	0	0	0	0		0	0	0
EPA	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NASA	0	0	0	0	0	0	0	0	0	0	2394	2463	2394	2463
NRC	120	120	0	0	0	0	0	0	0	0	0	0	120	120
TOTAL	1693533	1802752	564513	596371	127530	129969	22601	22110	455960	475349	5649	5141	2869786	3031692
% of FY TOTAL	59.0%	59.5%	19.7%	19.7%	4.4%	4.3%	0.8%	0.7%	15.9%	15.7%	0.2%	0.2%	100.0%	100.0%

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

TABLE 2.5 AGENCY SUPPORTING RESEARCH COSTS, BY SERVICE

(Thousands of Dollars)

AGENCY	Basic Meteorology FY2006	Basic Meteorology FY2007	Aviation FY2006	Aviation FY2007	Marine FY2006	Marine FY2007	Agriculture & Forestry FY2006	Agriculture & Forestry FY2007	General Military FY2006	General Military FY2007	Other FY2006	Other FY2007	Total FY2006	Total FY2007
Agriculture	0	0	0	0	0	0	39706	31395	0	0	0	0	39706	31395
Commerce/NOAA(Subtot)	120699	87662	1625	1625	500	500	0	0	0	0	0	0	122824	89787
NWS	21057	22130	0	0	0	0	0	0	0	0	0	0	21057	22130
NESDIS	31753	24771	0	0	0	0	0	0	0	0	0	0	31753	24771
OAR	66733	39605	1625	1625	0	0	0	0	0	0	0	0	68358	41230
NOS	0	0	0	0	500	500	0	0	0	0	0	0	500	500
NMAO	1156	1156	0	0	0	0	0	0	0	0	0	0	1156	1156
Defense(Subtot)	13266	10920	0	0	41427	42581	0	0	32527	35868	0	0	87220	89369
Air Force	0	0	0	0	0	0	0	0	28675	34899	0	0	28675	34899
DMSP*	0	0	0	0	0	0	0	0	3852	969	0	0	3852	969
Navy	0	0	0	0	41427	42581	0	0	0	0	0	0	41427	42581
Army	13266	10920	0	0	0	0	0	0	0	0	0	0	13266	10920
Homeland Security (Subtot)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
USCG	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Interior/BLM	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Transportation(Subtot)	0	0	21506	23600	0	0	0	0	0	0	4200	4200	25706	27800
FAA	0	0	21506	23600	0	0	0	0	0	0	0	0	21506	23600
FRA	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FHWA	0	0	0	0	0	0	0	0	0	0	4200	4200	4200	4200
EPA	0	0	0	0	0	0	0	0	0	0	9000	9000	9000	9000
NASA	0	0	0	0	0	0	0	0	0	0	162800	166400	162800	166400
NRC	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	133965	98582	23131	25225	41927	43081	39706	31395	32527	35868	176000	179600	447256	413751
% of FY TOTAL	30.0%	23.8%	5.2%	6.1%	9.4%	10.4%	8.9%	7.6%	7.3%	8.7%	39.4%	43.4%	100.0%	100.0%

*DMSP is the Defense Meteorological Satellite Program that supports all DOD Components and other government agencies. It is primarily funded and managed by the Air Force.

TABLE 2.6 PERSONNEL ENGAGED IN METEOROLOGICAL OPERATIONS
(Units are Full Time Equivalent Staff Years)*

AGENCY	FY 2006	FY 2007	% CHANGE	% of FY 2007 TOTAL
Agriculture	271	268	-1.1	2.0
Commerce/NOAA (Subtotal)	5,953	5,963	0.2	44.2
NWS	4,870	4,880	0.2	36.1
NESDIS	890	890	0.0	6.6
OAR	32	32	0.0	0.2
NOS	107	107	0.0	0.8
NMAO	54	54	0.0	0.4
Defense	5665	5516	-2.6	40.8
Air Force (Subtotal)	4,714	4,609	-2.2	34.1
Air Force Weather	4,594	4,490	-2.3	33.2
DMSP	120	119	-0.8	0.9
Navy	617	547	-11.3	4.1
Army	334	360	7.8	2.7
Homeland Security (Subtotal)	108	108	0.0	0.8
USCG	108	108	0.0	0.8
Interior/BLM (Subtotal)	28	28	0.0	0.2
Interior	26	26	0.0	0.2
Reimbursed**	2	2	0.0	0.0
Transportation (Subtotal)	3,695	1,728	-53.2	12.8
FAA	3,550	1,301	-63.4	9.6
FHWA	4	4	0.0	0.0
EPA	0	0	0.0	0.0
NASA	0	0	0.0	0.0
NRC	2	2	0.0	0.0
TOTAL	15,613	13,505	-13.5	100.0*

* Column total does not exactly equal 100 percent due to rounding for several agencies.
** “Reimbursed" are personnel funded by other agencies.

INTERAGENCY FUND TRANSFERS

Table 2.7 summarizes the reimbursement of funds from one agency to another during FY 2006. Agencies routinely enter into reimbursable agreements when they determine that one agency can provide the service more efficiently and effectively than the other. While specific amounts may vary from year-to-year, the pattern shown is essentially stable and reflects a significant level of interagency cooperation.

Department of Commerce. NESDIS will transfer a total of $199.3 million to NASA for procurement and launches of polar-orbiting ($72.2 million) and geostationary ($127.1 million) satellites.

Department of Defense. The Air Force will reimburse DOC a total of $19.765 million for operations [e.g., DMSP operations ($10.807 million), OFCM support ($140,000), Lightning Data ($695,000), NCEP operations ($14,000), WSR-88D support ($6,754,000), COMET training development ($225,000), geomagnetic data ($230,000), and IPO support ($216,000)]. In addition, the Air Force will reimburse NASA $1.414 million for a variety of data and USGS $350,000 for the purchase of magnetometer data support.

The Navy will reimburse DOC $209,000 for basic climatological analysis and forecasting, and interagency coordination.

The Army reimbursements to DOC/NOAA include $597,000 from COE to NWS for maintaining precipitation reporting stations The U.S. Geological Survey will also be reimbursed $500,000 by the Army's COE for operations and maintenance of hydrologic and precipitation reporting stations.

Department of Transportation. The FAA will reimburse NOAA $35.5 million for FY 2007. Included in those funds are development of enhancements and operational support associated with the WSR-88D, ASOS maintenance, the Center Weather Service Units at all Air Route Traffic Control Centers, the World Area Forecast System, meteorology instructors at the FAA, studies and OFCM support. The FAA will also reimburse the DOD a total of $3.4M for supporting research.

The FRA transferred $141,500 to NOAA's Global Systems Division (GSD) of the Earth System Research Laboratory (ESRL) in 2005, to fund the purchase of weather sensing equipment which was installed at the Nationwide Differential Global Positioning System (NDGPS) sites constructed in 2005. In 2006, FRA requested an increase in NDGPS funding to accelerate construction. Thus, FRA plans to transfer approximately $289,000 to GSD in 2006.

National Aeronautics and Space Administration (NASA). The Air Force will be reimbursed a total of $1.655 million--$1.500 million for observations, forecasts, and operations/maintenance of weather infrastructure and replacement of upper air systems at Trans-Atlantic Abort Landing Sites and $165 million for operation and maintenance of weather towers at Edwards AFB, CA. The UCAR will receive $15,000 for data analysis to improve lightning launch commit criteria. The National Data Buoy Center will receive reimbursements of $133,000 for the operation of two data buoys.

Environmental Protection Agency (EPA). NOAA's Air Resources Laboratory (ARL) will receive $6.7 million for development, evaluation, and application of air quality dispersion models; and for provision of meteorological expertise and guidance for EPA policy development activities.

Nuclear Regulatory Commission (NRC). The NRC enjoys a unique relationship with the DOE as a result of the Energy Reorganization Act of 1974. The act realigned the Atomic Energy Commission into a regulatory organization-NRC and a research and promotional organization-ERDA (which was subsequently absorbed into DOE). As a result, the NRC has access to the DOE national laboratories for technical assistance activities. This assistance, while not a reimbursable agreement, results in the transfer of funds from NRC for specific technical assistance by DOE laboratories. In FY 2006, the NRC expects to task DOE laboratories and the National Oceanic and Atmospheric Administration's National Climatic Data Center at a funding level of $120,000.

FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

Table 2.8 indicates the number of facilities/locations or platforms at which the Federal agencies carry out (or supervise) the taking of various types of meteorological observations.

TABLE 2.7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH

Agency Funds Transferred from:	Agency Funds Transferred to:	FY 2006 Funds ($K) Estimated or Planned: Operations	Supporting Research
Commerce/NOAA	NASA (Polar satellite acquisition)	72,274	
	NASA (Geo satellite acquisition)	127,061	
Defense/Air Force			
	NOAA(DMSP Satellite Operations)	10,807	
	DOC/NOAA/NWS (NEXRAD)		200
	DOC/NOAA/NWS (NEXRAD)	6,754	
	DOC/NOAA/NWS (ASOS)		138
	DOC/NOAA/NWS (ASOS)	705	
	DOC/NOAA (Shared Processing Network	105	
	DOC/NOAA/NWS/NCEP(NCEP Communication Circuit Support)	14	
	DOC/NOAA (COMET)		225
	DOC/NOAA/NWS (Lightning Detection System)	695	
	DOC/NOAAOFCM	140	
	DOC/NOAA/NESDIS/IPO (DMSP: Activation of DOMSAT)	216	
	USGS (Dept. of Interior) (USGS Magnetometer)	350	
	NASA (JPL Tech Data)	210	
	DOC/NOAA/SEC (ACE Radian / Data Geomagnetic)	230	
	NSF (Universal Center for Atmos Research)		43
	NSF/UCAR/NCAR (WRF)		3,565
	NSF/UCAR (Data Assimilation)		500
	DOC/NOAA/ESRL (WRF)		50
	NASA (Land Information System)		1,414
Defense/Navy	DOC/NOAA/NCDC	44	
	DOC/NOAA/OFCM	165	
Defense/Army	DOD/USAF/ACC	122	
	DOC/NOAA/ETL		40
	NSF		44
	NSF		53
	DOC/NOAA/NWS	50	
	DOI/USGS	500	
	DOC/NOAA/NWS	597	
	DOC/NOAA/OFCM	65	

TABLE 2.7 INTERAGENCY FUND TRANSFERS FOR METEOROLOGICAL OPERATIONS AND SUPPORTING RESEARCH (Continued)

Agency Funds Transferred from:	Agency Funds Transferred to:	FY 2006 Funds ($K) Estimated or Planned: Operations	Supporting Research
Transportation/FAA	DOC/NOAA	35,500	
	DOD/USAF		3,400
	DOC/NOAA/OFCM	200	
Transportation/FRA	DOC/NOAA	289	
NASA	DOD/USAF/45th SW	1,500	
	DOD/USAF/Edwards AFB	165	
	DOC/NOAA/NDBC	133	
	UCAR		15
EPA	DOC/NOAA/OAR		6,700
NRC	DOE/PNNL	120	

TABLE 2.8 FACILITIES/LOCATIONS FOR TAKING METEOROLOGICAL OBSERVATIONS

TYPE OF OBSERVATION/AGENCY	No. of Locations (FY 2006)
Surface, land	
Commerce (all types)	841
Air Force (U.S. & Overseas)	162
Navy (U.S. & Overseas)	68
Marine Corps (U.S. & Overseas)	13
Army (U.S. & Overseas)	47
Transportation (Flight Service Stn)	8
Transportation (Lim Aviation Wx Rptg Stn)	114
Transportation (Contract Wx Obsg Stn)	189
Transportation (Auto Wx Obsg Stn)	198
Transportation (Road Wx Obsg Stn)	2,149
Transportation (Auto Sfc Obsg Sys, fielded)	569
Homeland Security (USCG Coastal)	50
Interior	470
Agriculture	1595
NASA (all types)	46
Surface, marine	
Commerce (SEAS-equipped ships)	140
Commerce (Coastal-Marine Autom Network)	65
Commerce (NOAA/NOS/PORTS)	6
Commerce (Buoys--moored)	64
Commerce (Buoys--drifting)	21
Commerce (Buoys--large navigation)	10
Commerce (Water-level gauges)	*175
*Number of which have meteorology sensors	59
Navy (Ships with met personnel)	29
Navy (Ships without met personnel	288
Homeland Security (USCG Cutters)	248
NASA (Buoys - moored)	2
Upper air, balloon	
Commerce (U.S.)	86
Commerce (Foreign, Cooperative)	22
Air Force, Fixed (U.S. & Overseas)	12
Air Force, Mobile	15
Army, Fixed (U.S. & Overseas)	18
Army, Mobile (U.S. and Overseas)	85
Navy, Fixed (U.S. & Overseas)	11
Navy, Mobile(U.S. & Overseas)	47
Navy, Ships	29
Marine Corps, Mobile	10
NASA (U.S.)	1
Atmospheric Profilers	
Air Force (Eastern Range)	5
Air Force (Western Range)	6
Army	9
NASA	1

TYPE OF OBSERVATION/AGENCY	No. of Locations (FY 2006)
Upper air, rocket	
Army (U.S. & Overseas)	1
Doppler weather radar (WSR-88D) sites	
Commerce (NWS)	123
Air Force (U.S. & Overseas)	26
Army (U.S. & Overseas)	2
Transportation (Off CONUS	12
Doppler weather radar (Not WSR-88D) sites	
Air Force (Fixed)	9
Army	2
Navy (Fixed)	9
Marine Corps (Mobile)	10
Marine Corps 9Fixed)	1
Off-site WSR-88D Processors (PUPs)	
Commerce (NWS) [Part of AWIPS]	0
Air Force (OPUPs only)	97
Marine Corps (U.S. & Overseas)	9
Army	1
Transportation	25
NASA (KSC/AMU)	1
Airport Terminal Doppler weather radars	
Transportation (Commissioned)	45
Army (not airfield--Test Range/USAREUR)	2
Conventional radar (non-Doppler) sites	
Commerce (NWS)	31
Commerce (at FAA sites)	27
Air Force, Mobile Units	23
Army (U.S. and Overseas)	4
Transportation (FAA (WSP))	34
Weather reconnaissance (No. of aircraft)	
Commerce (NAMO)	3
Air Force Reserve Command (AFRC)	10
Geostationary meteorological satellites (No. operating)	
Commerce (2 primary, 2 standby, 1 post launch checkout)	5
Polar meteorological satellites (No. operating)	
Commerce (2 primary, 4 standby)	6
Air Force (2 primary, 3 standby)	5
Navy (WINDSAT AND GFO)	2
Field Mills (Surface)	
NASA (KSC)	31

SECTION 3

DEPARTMENT OF COMMERCE WEATHER PROGRAMS
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

The National Oceanic and Atmospheric Administration (NOAA) is the principal meteorological agency of the Federal government. By law, NOAA is responsible for reporting the weather of the United States, providing weather and flood warnings and forecasts to the general public, developing and furnishing applied weather services, and recording the climate of the United States. This mission is carried out within NOAA by the National Weather Service (NWS); the National Environmental Satellite, Data, and Information Service (NESDIS); the Office of Oceanic and Atmospheric Research (OAR); the National Ocean Service (NOS); and the NOAA Marine and Aviation Operations (NMAO).

NATIONAL WEATHER SERVICE

NOAA's National Weather Service (NWS) has the principal responsibility for planning and operating the basic climate, hydrologic, and weather services and certain specific applied services. The NWS provides climate, water, and weather warnings and forecasts for the U.S., it's territories, adjacent waters, and ocean areas to help protect life and property and enhance the national economy. NWS data and products form a national information data base and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. In support of this mission, NWS:

- Issues warnings and forecasts of weather, flood, Great Lakes, coastal and ocean conditions.
- Observes and reports the weather and the river and ocean conditions of the U.S. and its territories.
- Develops and operates national meteorological, hydrological, climate, space weather and oceanic service systems.
- Performs applied meteorological, hydrological, space environmental and climate research.
- Assists in developing community awareness and educational materials and programs concerning weather-related natural disasters.
- Participates in international hydrometeorological and space weather activities, including the exchange, coding and monitoring of data and forecasts, and also including the installation and repair of hydrometeorological equipment and systems overseas under the Voluntary Cooperation Program.

The basic enabling legislation and authority for weather services are summarized as follows:

- Organic Act of 1890 created the United States Weather Bureau in the Department of Agriculture.
- Enabling Act of 1919 allowed the United States Weather Bureau to enter into cooperative agreements for providing agriculture weather services.
- Flood Control Act of 1938 authorized the establishment, operation, and maintenance of the Hydroclimatic Network by the Weather Bureau for Flood Control; on July 1, 1940, the Weather Bureau was transferred from the Department of Agriculture to the Department of Commerce.
- Federal Aviation Act of 1958 outlined duties of the Secretary of Commerce for providing weather observations and services to aviation.
- Reorganization Plan 2 of 1965 placed the "National Weather Service" in the newly created Environmental Science Services Administration (ESSA).
- Reorganization Plan 4 of 1970 made the NWS a part of the newly created National Oceanic and Atmospheric Administration (NOAA).
- International Convention for the Safety of Life at Sea (SOLAS) agreement to which the U.S. is signatory. This sets international policy for safer shipping and cleaner seas. The U.S implements the convention through Executive Order 12234 of Sept. 3, 1980 -- *Enforcement of the Convention for SOLAS*. Among the obligations of the agreement is to provide meteorological warnings and forecasts to ships at sea using charts and radio messages.

SERVICES

NWS provides climate, water, weather and space weather prediction services; including watches, warnings, advisories, and forecasts 24 hours a day, seven days a week. These services are provided through a national network of 122 Weather Forecast Offices (WFOs), 13 River Forecast Centers (RFCs), and the nine centers of the National Centers for Environmental Prediction (NCEP). These offices collect data, prepare local warnings and forecasts, and disseminate information to the public both nationally and internationally through NOAA Weather Radio, satellite-based telecommunication systems, radiofacsimile, the media and the internet. Forecast and warning services prepared at WFOs are derived in part from prediction guidance prepared by the 13 RFCs and the nine NCEP centers. These centers are: Hydrometeorologi-

cal Prediction Center, Storm Prediction Center, Aviation Weather Center, Environmental Modeling Center, Tropical Prediction Center, Climate Prediction Center, Space Environment Center, Ocean Prediction Center, and NCEP Central Operations.

Continually improving the accuracy, timeliness, and accessibility to prediction services is largely a result of research and development both within the NWS and externally from universities and private corporations.

PUBLIC WEATHER SERVICES

NOAA's NWS Public Weather Service Program provides forecast, warning, and response services to the public, private meteorological firms, broadcast meteorologists, and NWS partners who are responsible for public safety. These partners include Federal, state, and local emergency managers and planners. NWS forecasters issue short-duration watches and warnings for severe weather, such as tornadoes and severe thunderstorms, as well as long-duration watches, warnings, and advisories for hazardous winter weather conditions, high wind events, dense fog, and temperature extremes. NWS forecasters support several health related programs such as Air Quality, Heat Health, and the Ultraviolet Index (UVI). Ground based ozone concentration forecasts and an experimental smoke forecasting tool are now being produced for the CONUS. A nationwide air quality forecast capability including concentrations of aerosols, particulate matter, and other pollutants is under development. Heat Health Watch Warning Systems (HHWWS) have been developed for select cities to provide advance notice of excessive heat events that produce the greatest number of weather-related deaths. These guidance systems will be expanded to other cities as resources are made available. Also, in partnership with the Environmental Protection Agency (EPA), a new climatologically based UV alert is being produced for the entire nation. The Branch serves as the primary focal point for collaboration with Federal transportation agencies on weather issues related to surface transportation, with Federal, media, and private entities on the UVI, and with the World Meteorological Organization on the provision of public weather services to the international community. Additionally, NWS forecasters provide meteorological support both on-site and from WFOs for terrorist acts and other homeland security concerns, as well as accidental releases/spills of hazardous chemical, biological, or radioactive materials.

Since 2004, the National Weather Service has created, and made readily available, forecasts in digital formats. NWS forecasters use their expertise to maintain an up-to-date digital forecast database of sensible weather elements. This information is stored in the National Digital Forecast Database (NDFD). Output from NDFD is available in the form of web graphics available over the Internet, in gridded binary format (GRIB2) available via anonymous file transfer protocol, or in XML via an experimental web service. NDFD data can also be converted to a file format that can be used with Geographical Information Systems (GIS). NDFD includes the following operational forecast elements: Maximum Temperature, Minimum Temperature, 12-Hour Probability of Precipitation, Temperature, Dew Point, Weather, Wind Speed and Direction and derived elements Relative Humidity and Apparent Temperature. Experimental forecast elements include Quantitative Precipitation Forecast (QPF), Snow Amount, Significant Wave Height and Sky Cover. For more detailed information on NDFD, please see http://www.nws.noaa.gov/ndfd/.

AVIATION WEATHER SERVICES

The NWS provides a broad range of services in support of the aviation community. The WFOs prepare Terminal Aerodrome Forecasts (TAFs) four times a day, with amendments as needed, for more than 590 public-use airports in the U.S. and it's territories in the Caribbean and Pacific. These offices also produce about 241 individual route-oriented forecasts three times a day for the 48 contiguous states and over the Pacific Ocean.

NCEP's Aviation Weather Center (AWC) and the Alaska Region's Alaska Aviation Weather Unit (AAWU), and WFO Honolulu, HI prepare area forecasts three or four times daily describing general aviation weather conditions over the lower 48 states, the Gulf of Mexico, Caribbean, Alaska, Hawaii and coastal waters respectively. These three specialized offices also issue in-flight advisories and warnings of hazardous weather conditions associated with thunderstorms, icing, turbulence, and strong, low level winds. The AWC also prepares forecasts of significant aviation weather over the continental U.S. four times a day for flight levels from the surface to 25,000 feet.

NWS Center Weather Service Units located in each of the 21 FAA Air Route Traffic Control Centers provide direct meteorological support to en route centers, Terminal Radar Approach Controls, airport towers, and Automated Flight Service Stations.

The NWS provides a service to international aviation as one of the International Civil Aviation Organization's (ICAO's) two World Area Forecast Centers. NCEP's Environmental Modeling Center supplies global gridded model data of temperature, winds, and humidity twice a day for flight levels from 5,000 to 45,000 feet. The AWC prepares forecasts four times a day of globally significant thunderstorms, tropical cyclones, severe squall lines, moderate or severe turbulence and icing, and cumulonimbus cloud associated with the above, from 25,000 to 63,000 feet. The forecast charts also

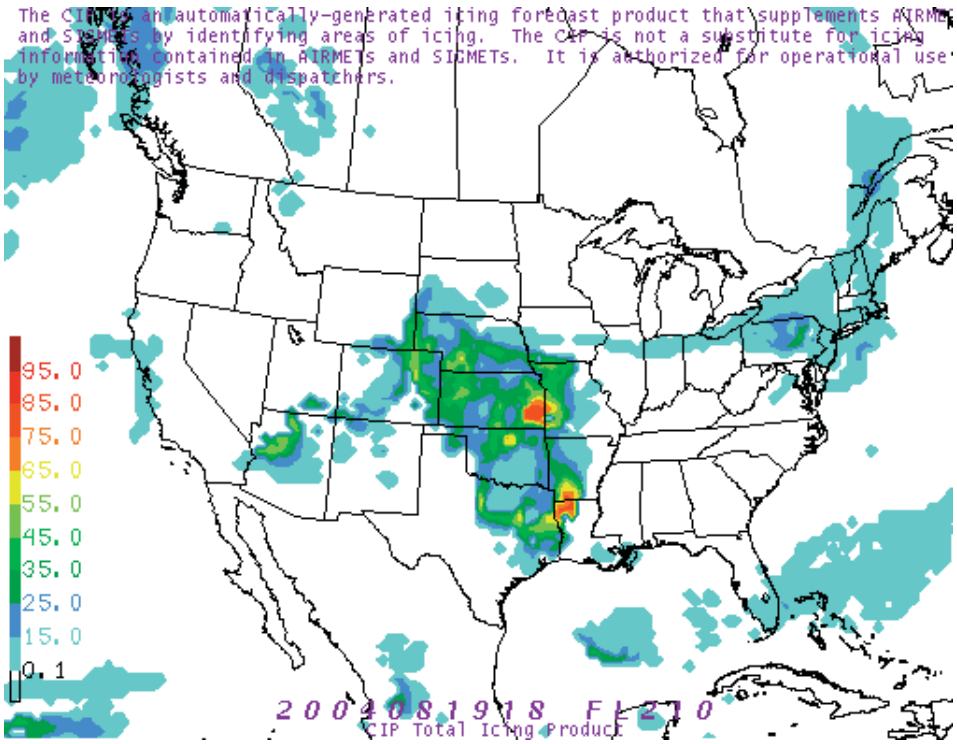


Figure 3-DOC-1. Current Icing Potential (CIP) Product. The FAA's Aviation Weather Research Program and the NWS developed this graphical icing product, updated every 3 hours, and available for user selected altitudes across the contiguous U.S.

include information on volcanoes, radiological releases, jet streams and tropopause heights. This information is transmitted by the International Satellite Communications System with coverage in the Americas, Caribbean, western portions of Europe, the Pacific, and eastern Asia.

Within the framework of the international airways volcano watch, the NWS and NCEP share management responsibility for operating the Volcanic Ash Advisory Centers (VACC) in Washington state and Anchorage, Alaska.

The NWS, working closely with the FAA's Aviation Weather Research Program, developed new experimental and operational forecast products designed to improve aviation hazard forecast capabilities zero to six hours into the future (Figure 3-DOC-1).

New icing and turbulence products for meteorologists and end users became operational in FY 2004. Improved software tools to increase the number of terminal airports covered by a forecast are also under development.

MARINE WEATHER SERVICES

The NWS Marine Weather Program is the lead for the nation's marine and coastal weather services. Programs include warnings, forecasts, and advisories for coastal waters, offshore, high seas, and near-shore and open waters of the Great Lakes. It leads programs for tropical cyclone, coastal flood, severe convective coastal weather, and coastal hazards such as high surf, rip currents, and tsunamis. NWS forecasters at 46 coastal and marine WFOs, in collaboration with NCEP's Ocean Prediction Center and Tropical Prediction Center, provide a range of weather services focused on the expanding and weather-sensitive U.S. coastal population and those responsible for its safety.

The program develops plans, policy and procedures for the delivery of marine and coastal weather products and services from the coastal WFOs, the Ocean Prediction Center, the Tropical Prediction Center, and the Central Pacific Hurricane Center. It ensures marine and coastal forecast training needs are met. The program works with the Office of Science and Technology to prioritize tropical, marine and coastal science and technology development and approve new or improved product designs, and with the Office of Operational Systems to ensure the collection of marine and coastal observations and the delivery of marine and coastal products to users. The program creates internal and external partnerships, collects and validates marine and coastal service and mission needs, solicits feedback on products and services and validates whether these needs are met.

The program works with NOAA's NESDIS, the U.S. Navy and the U.S. Coast Guard (USCG) to provide ice warning and advisory services through the joint National Ice Center; with the Navy, the USCG, the U.S. Maritime Administration, and the Corps of Engineers to safely operate the nation's Marine Transportation System; with the Department of Defense, Federal Emergency Management Agency, and Corps of Engineers to provide tropical cyclone services; with the USCG, Navy, Air Force, and private entities to disseminate weather to mariners; with NOAA's National Ocean Service (NOS) on the PORTS and TIDES programs; and with the World Meteorological Organization to provide services to the international community. It also works in cooperation with NOAA's Office of Response and Restoration, the Department of Defense, and Department of Homeland Security for forecasting services for hazardous material spills, marine area search, rescue, and recovery operations, and security needs.

FIRE/ALL HAZARD WEATHER SERVICES

NOAA's NWS offices provide rou-

tine pre-suppression and wildfire weather support to Federal and state land management agencies. NWS forecasters provide routine fire weather forecasts, forecast support for the National Fire Danger Rating System, and site specific forecasts during the local fire season over roughly three-quarters of the nation. The NWS deploys a national cadre of specially-trained Incident Meteorologists (IMETs) to large wildfires and coordination centers for on-site weather support. IMETs use weather instrumentation, telecommunications, and display equipment to aid in on-site forecast preparation and briefings. In the early morning, NOAA's National Centers for Environmental Prediction's Storm Prediction Center issues outlooks for days 1, 2 and 3 to 8, that highlight areas with critical and extremely critical fire potential based on the state of the fuels (trees, brush, grasses), and critical weather parameters. Areas where significant lightning activity accompanied by less than 0.1 inch of precipitation (dry lightning) is forecast are also highlighted. Additionally, NWS forecasters provide forecasts in response to hazardous material incidents or Incidents of National Significance (such as the Columbia Recovery effort).

TSUNAMI WARNINGS

Tsunami watches, warnings, and information bulletins for the Pacific Ocean and Hawaii are prepared by the Richard H. Hagemeyer Pacific Tsunami Warning Center in Ewa Beach, Hawaii, and for west coast of the continental U.S. and Alaska by the West Coast/Alaska Tsunami Warning Center in Palmer, Alaska. NWS collects and analyzes observational data from an international network of seismological observatories, sea-level observing stations, and deep-ocean tsunami detection buoys which operate on a cooperative basis. The centers use these data to prepare and disseminate watches, warnings, and information bulletins to international customers, WFOs, Federal and state disaster agencies, military organizations, private broadcast media, and other agencies involved with warning the public.

CLIMATE SERVICES (CS)

Climate prediction products and other services relate to the period of week two out to one year, including seasonal forecasts and hazard assessments. The NWS's Climate Prediction Center produces a suite of products covering these periods. The climate services program provides the strategic vision for climate services at NWS, oversees the program including the expanded regional and local climate services programs, and serves as steward of the climate observing system. It maintains strong ties with other countries; across NOAA lines, specifically through the NOAA Climate Office; with Federal agencies; the university community; and the private sector and encourages collaborative arrangements among the Regional Climate Centers (managed by NOAA/NESDIS), the State Climatologists, and NWS WFOs and regional headquarters to tailor climate forecasts for local users.

HYDROLOGIC SERVICES

The 122 WFOs, 13 River Forecast Centers (RFCs), and NCEP's Hydrometeorological Prediction Center (HPC) work as a team to provide hydrologic forecast and warning services which minimize loss of life and property damage from flooding and to meet the water service needs of our Nation. RFC hydrologists use a modeling system called the NWS River Forecast System (NWSRFS) to produce forecast time series of discharges or river stages at approximately 4,000 locations along the nation's rivers. HPC provides the quantitative precipitation forecasts serving as the primary forecast input for NWSRFS. RFCs also provide long-term water supply forecasts used by water managers in the western U.S., where decisions about water allocation and use are particularly critical now, with much of the West still feeling the effects of a long-term drought.

WFOs work cooperatively with the RFCs to monitor the major river systems around the clock. Using RFC guidance, advanced Doppler radar (NEXRAD) and telemetered rain gauge observations, WFOs continuously monitor the threat of flash flooding and urban flooding to provide timely flood watches and warnings to protect life and property.

Partnerships with a variety of Federal, state and local agencies are critical to NOAA's NWS Hydrologic Services Program. For example, the NWS works very closely with the United States Geological Service (USGS), the United States Army Corps of Engineers, the Natural Resources Conservation Service (NRCS), the Bureau of Reclamation, and the Bureau of Land Management on a variety of water related issues including stream gauging, support of flood fighting activities, river and water supply forecasting, and water management. River stage observations and stage-discharge relationships provided by the USGS are critical to warning and forecast operations for the Nation's rivers. The NRCS furnishes snow measurements that are combined with advanced snow modeling and analysis provided by NOAA's National Operational Hydrologic Remote Sensing Center to support joint NWS-NRCS water supply forecasting in the western U.S.

The NWS is implementing the Advanced Hydrologic Prediction Service (AHPS) to provide hydrologic forecasts with lead times ranging from minutes to months. AHPS builds on the existing NWS infrastructure, including AWIPS, NEXRAD, and NWSRFS. AHPS also provides Ensemble Streamflow Prediction, a feature that allows the NWS to quan-

tify forecast uncertainty. This lets decision makers apply risk-based analyses as they respond to flooding, and as they try to balance competing demands on water supply, especially during periods of drought.

Flash floods, typically caused by intense, small-scale convection, are the leading cause of flood fatalities. Another AHPS capability, known as Flash Flood Monitoring and Prediction (FFMP), combines high-resolution radar rainfall observations with Geographic Information System (GIS) technology to provide more accurate and much more precise flash flood forecasts. The added precision provided by FFMP greatly reduces the false alarm rate of flash flood forecasts, making them more credible and leading to better public response, which will ultimately save lives.

AHPS services are provided as a suite of Web-based products (weather.gov/ahps), that feature user-friendly menus and maps which allow users to zoom in to areas of interest. Clicking on an area of interest on the national map brings the user to a map of the NWS WFO serving that area which provides more detailed information on river conditions. AHPS also opens opportunities to improve NOAA's analysis and forecast capabilities related to coastal water conditions, through joint efforts with other components of NOAA (e.g., National Ocean Service, Office of Oceanic and Atmospheric Research).

OBSERVATIONS

Observations form the basis for forecasts and the monitoring and evaluation of the environment. Differing applications and requirements are associated with each of these functions. Forecast applications associated with watch and warning functions must be served immediately, while real-time availability is not a significant factor for climate monitoring. The range of differing applications will dictate how future instrument deployments will be conducted. This poses a constant challenge to the optimization of resources placed into in-situ and remotely sensed observation platforms.

The fundamental application of observations is to deliver better products and improve services. This demands the link between improved services and observing systems be well defined. We need to determine the gaps in observations to meet varied requirements, emphasizing the importance of metadata and sensor calibration continuity. Coordinated efforts within the Federal community throughout all aspects of observations development, dissemination and use are needed for efficient utilization of resources.

The NWS approach for improving observations consists of several efforts:

- Make better use of data from observing systems that currently exist;
- Extend the system life of current observing systems to postpone technical obsolescence;
- Replace obsolete observing systems;
- Implement new observing tech-

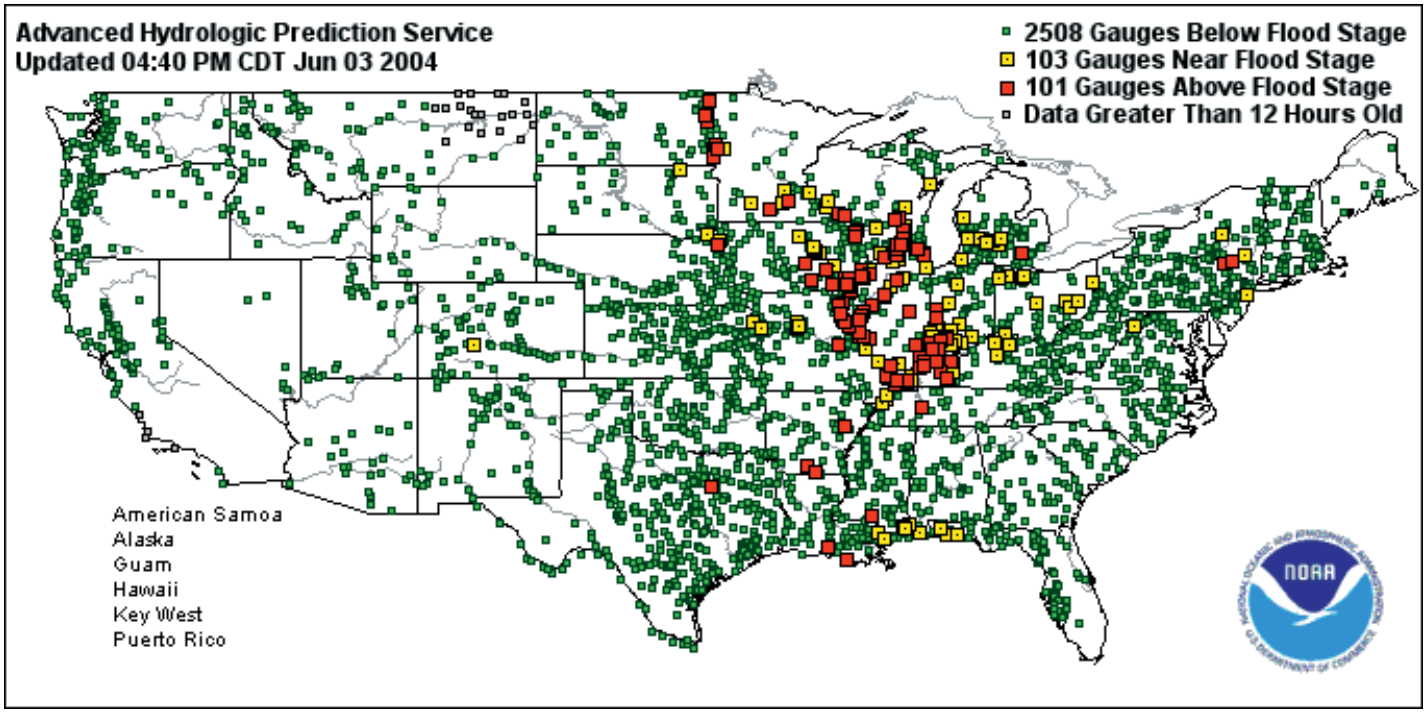


Figure 3-DOC-2. Map showing status of river conditions throughout the Nation. This map is included on the primary AHPS Web page and it provides access to more detailed local information on river conditions, including observations and forecasts at specific locations along rivers, as well as expected impacts that could result from flooding.

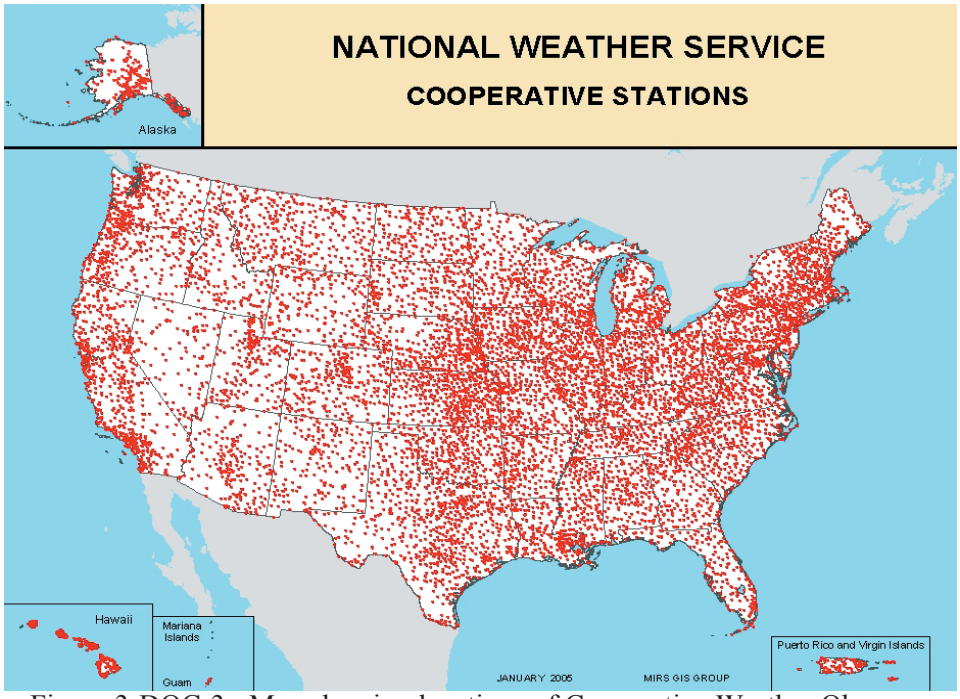


Figure 3-DOC-3. Map showing locations of Cooperative Weather Observer Network (COOP). Interactive web site can be found at *http://www.nws.noaa.gov/om/coop/wfo-rfcmap.htm*

nologies and communication systems that better meet the data needs of our customers; and

• Strengthen the link between user requirements and technology research and development.

The NWS manages programs that produce observations in support of a wide range of customers, such as the aviation, climate monitoring and research communities. As part of its responsibility, the NWS inspects all surface weather observing stations and certifies equipment and observers. NWS Headquarters establishes policy for observations and standards and coordinates with other Government agencies and international organizations.

NOAA'S COOPERATIVE WEATHER OBSERVER NETWORK (COOP)

THE COOP is the Nation's largest and oldest weather network. Modernization of the COOP under NERON is consistent with the President's Climate Change Research Initiative, providing a richer source of data to improve weather, water and climate forecasting and to contribute to climate change research. The COOP is the primary source for monitoring U.S. climate variability over weekly to interannual time frames. These data are also the primary basis for assessments of century-scale climate change. The modernized network will add to NOAA's vision of an-end-to-end monitoring program that "takes the temperature" of the earth's systems.

NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION

NCEP delivers analyses, guidance, forecasts and warnings for weather, ocean, climate, water, land surface and space weather to the nation and world. NCEP provides science-based products and services through collaboration with partners and users to protect life and property, enhance the Nation's economy and support the Nation's growing need for environmental information. Each service center depends on the observational infrastructure, the data assimilation systems, the numeric modeling function, and the application of model output statistics to produce value added forecast guidance products for NWS field offices and other users.

NCEP is organized into seven science-based, service-oriented centers that generate environmental prediction products and two central support centers that develop and operate numerical models -- the basis for NWS predictions.

Storm Prediction Center

The Storm Prediction Center (SPC) focuses on hazardous weather events, such as severe thunderstorms, tornadoes, extreme winter weather, fire weather, and excessive precipitation with emphasis on the forecast period that ranges from 2-8 hours to the next 6 to 72 hours. All Tornado and Severe Thunderstorm Watches issued anywhere in the contiguous U.S. come from the SPC in collaboration with local NWS Forecast Offices. Also, the SPC prepares Mesoscale Convective Discussions which are technical explanations of developing mesoscale features and their impact on hazardous weather. For longer time periods, the SPC produces the Convective Outlook which is the one-, two- or three-day forecasts of the probability and intensity of both non-severe and severe thunderstorms (including tornadoes). The SPC also issues one- and two-day Fire Weather Outlooks for the contiguous U.S. defining areas with critical, extremely critical and dry thunderstorm fire conditions and potential for defined areas.

Hydrometeorological Prediction Center

The Hydrometeorological Prediction Center (HPC) provides forecast, guidance, and analysis products and services (1) to support the daily public forecasting activities of the NWS and its customers, and (2) to provide tailored support to other government agencies in emergency and special situations. As part of this mission, HPC prepares Quantitative Precipitation

Forecasts (QPF) used by the RFCs to develop local river and flood forecasts and by WFOs to develop local rainfall, snow and ice forecasts. The HPC provides special QPFs and coordinates with other Federal agencies, such as the Federal Emergency Management Agency (FEMA), during major flood events. The HPC also provides an array of analyses and forecasts out to seven days of frontal systems, pressure patterns, temperature, and precipitation for use by WFOs and the private weather community. Additionally, HPC serves as the backup to the National Hurricane Center.

Aviation Weather Center

The NCEP experts for aviation meteorology are concentrated at the Aviation Weather Center (AWC). The AWC provides weather warnings, advisories and forecasts to the aviation community under an international agreement through the International Civil Aviation Organization. The AWC provides wind, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and en route aircraft operations for the U.S., the Gulf of Mexico, the Caribbean Sea, the Atlantic and Pacific routes in the Northern Hemisphere and some routes in the Southern Hemisphere.

Environmental Modeling Center

The Environmental Modeling Center (EMC) improves NCEP's numerical climate, water, and weather predictions through data assimilation and computer modeling. To provide mesoscale predictions (thunderstorms, hurricanes, tornadoes, blizzards, etc.), ocean predictions and global weather and climate predictions, EMC develops, adapts, improves, and monitors data assimilation systems and global, regional and mesoscale models of the atmosphere, land surface, ocean, and atmosphere/ocean/land systems. The EMC uses advanced modeling methods developed internally and cooperatively with universities, the international scientific community, NESDIS, NOAA laboratories, and other government agencies. As an example, EMC is a partner in the NASA/NOAA Joint Center for Satellite Data Assimilation (JCSDA) designed to accelerate the use of research and operational satellite data in NCEP operational models. The EMC integrates research and technology through collaborative model development projects. These interactions serve as an efficient and effective interface between NCEP and the scientific community that develop ideas, numerical models, and forecast techniques to implement model improvements and improve NWS products. The EMC conducts applied research and technology transfers and publishes research results in various media for dissemination to the world meteorological, oceanographic, and climate community. EMC also participates in ongoing interactive research programs such as the USWRP Hurricane at Landfall project and the community Weather Research and Forecast (WRF) model. Furthermore, EMC is participating in the Winter Storm Reconnaissance Program in the Pacific through targeted observations aimed at improving forecasts across the country. EMC efforts with collaborative development have resulted in improvements to mesoscale and global models, as well as advancements in hurricane track forecasts, climate forecasts and air quality forecasts.

Climate Prediction Center

The Climate Prediction Center (CPC) provides operational monitoring and prediction of global and regional climate variability, with emphasis on applied research and partnerships, to improve understanding of the global climate system, weather and climate links, extremes and trends. CPC develops and maintains data bases for determining current and historical climate anomalies and trends, and provides analyses and assessments of their origins and linkages to the global climate system. CPC products and services cover time scales ranging from next week (days 6-10) to seasons and out to a year in advance, and cover land, ocean, and atmosphere extending into the stratosphere. CPC's products include probabilistic long range outlooks for temperature and precipitation, the multi-agency U.S. Drought Monitor (a drought outlook), and El Niño Southern Oscillation (ENSO) discussions and outlooks, among many others. WFOs, as well as the public, private industry, and the national and international research community use CPC products and climate services.

Space Environment Center

The Space Environment Center (SEC) provides national and international forecasts, alerts, and warnings of extraordinary conditions in the space environment, solar radio noise, solar energetic particles, solar X-ray radiation, geomagnetic activity, and conditions of stratospheric warming. The SEC observes, assesses, and predicts activity in the space environment to promote public safety and to mitigate economic loss that could result from disruption of satellite operations, communications and navigation systems, and electric power distribution grids. The SEC issues to the public, its U.S. Air Force partners, and vendors of value-added services specific predictions of the space weather activity level for the next three days and more general predictions up to several weeks in advance, as well as weekly summaries of observed solar terrestrial conditions. SEC serves as the international World Warning Agency for the International Space Environment Service (ISES). It exchanges international data- solar wind, X-ray, sunspot, corona, magnetic, and ionospheric measurements-in real-time and, from these data, provides and meets additional specific needs of other government agencies. SEC distributes (receives) data to (from) other countries and issues a consensus set of daily forecasts for international use.

Ocean Prediction Center

The Ocean Prediction Center (OPC) provides atmospheric and oceanographic warning, forecast, and analysis products and services for the North Atlantic and North Pacific (north of 30 degrees) as part of the NWS mission of protecting life and property and enhancing economic opportunity (Figure 3-DOC-4). As part of this responsibility, OPC handles U.S. international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). The OPC provides weather and sea state warnings and forecasts for the offshore waters of the U.S. and the high seas of the Northern Hemisphere, north of 30 degrees, for planning and operational purposes. OPC warnings and products go directly to ships and are vital for the protection of life and property at sea, and enhancement of the economy. The OPC also coordinates forecasts with and provides forecast guidance to WFOs with coastal responsibilities. The OPC, the Tropical Prediction Center (TPC), HPC, and WFO Honolulu, HI collaborate daily to produce unified and seamless surface weather analyses covering from 30 degrees South to the North Pole, and from East Asia across the Pacific and Atlantic to Western Europe and Africa.

Tropical Prediction Center/National Hurricane Center

The NCEP experts in the area of tropical meteorology are concentrated in the Tropical Prediction Center (TPC)/National Hurricane Center (NHC). TPC/NHC services include public and marine advisories, watches, and warnings for tropical cyclones in the North Atlantic and eastern North Pacific hurricane basins including the portions of the coastline threatened by such storms. In addition, TPC forecasters provide marine analyses and forecast products for the same areas of responsibility, south of 30 degrees north latitude and a portion of the southeast Pacific. TPC warnings and products go directly to ships and are vital for the protection of life and property at sea, and enhancement of the economy. The TPC/NHC provides guidance, coordination, and tropical weather expertise to WFO forecasters, the media, and private industry.

NCEP Central Operations

The NCEP Central Operations (NCO) is responsible for NCEP operations, including access to real-time data, and its quality control and use in numerical weather prediction systems, as well as the workstations used by NCEP forecasters to access model output and other data necessary for producing guidance products. The NCO provides management, procurement, development, installation, maintenance, and operation of all computing and communications related services that link individual NCEP activities together. The NCO is the focal point for establishing and executing policies, standards, procedures, and documentation for computing and communications within the entire NCEP organization. The NCO maintains and manages the supercomputer and runs the computer applications that generate all NCEP model products. The NCO leads the technical transition between the research and development of numerical weather and climate prediction models and their operational use on the NCEP computer systems. In addition, NCO provides 24-hour information services and operational support for NCEP computing systems, including the network which ties together internal NCEP communications, NWS high performance computer systems, forecaster workstations, personal computers and a user service that support all NCEP centers. Since an upgrade to NCEP's main computer systems and facilities in 1999, and throughout subsequent upgrades, NCO has delivered NCEP model forecasts and products to its users with a high degree of reliability and timeliness.

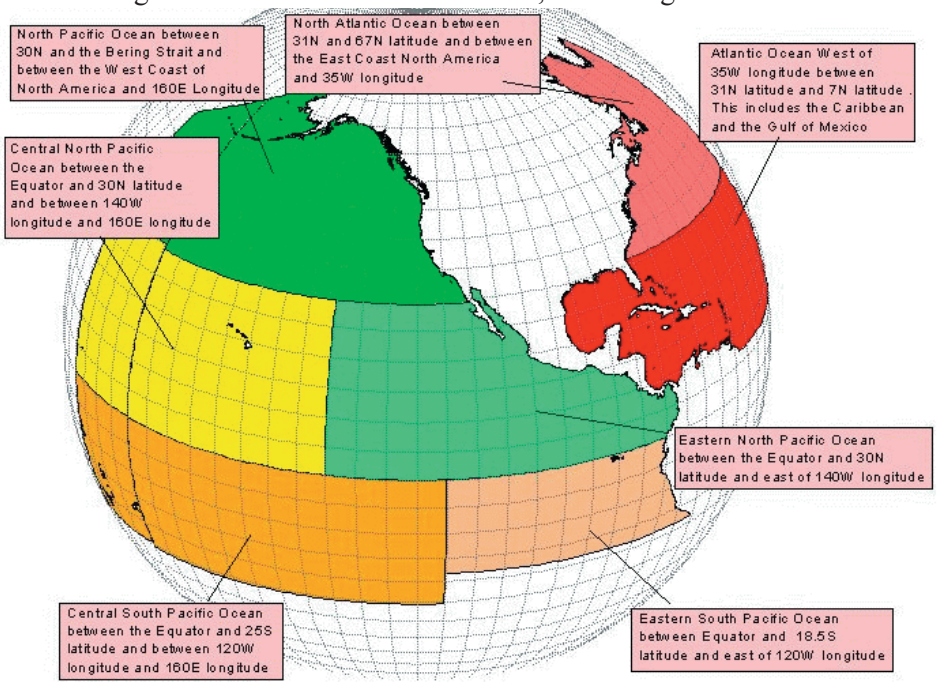


Figure 3-DOC-4. United States High Seas Forecast Areas of Responsibility.

Other NWS Offices with National Responsibilities

In addition to the NCEP centers, there are two other offices that provide National products. They are the Alaska Aviation Weather Unit and the WFO Honolulu/Central Pacific Hurricane Center.

Alaska Aviation Weather Unit. The Alaska Aviation Unit (AAWU) provides wind, temperature, and flight hazards (e.g., icing, turbulence) fore-

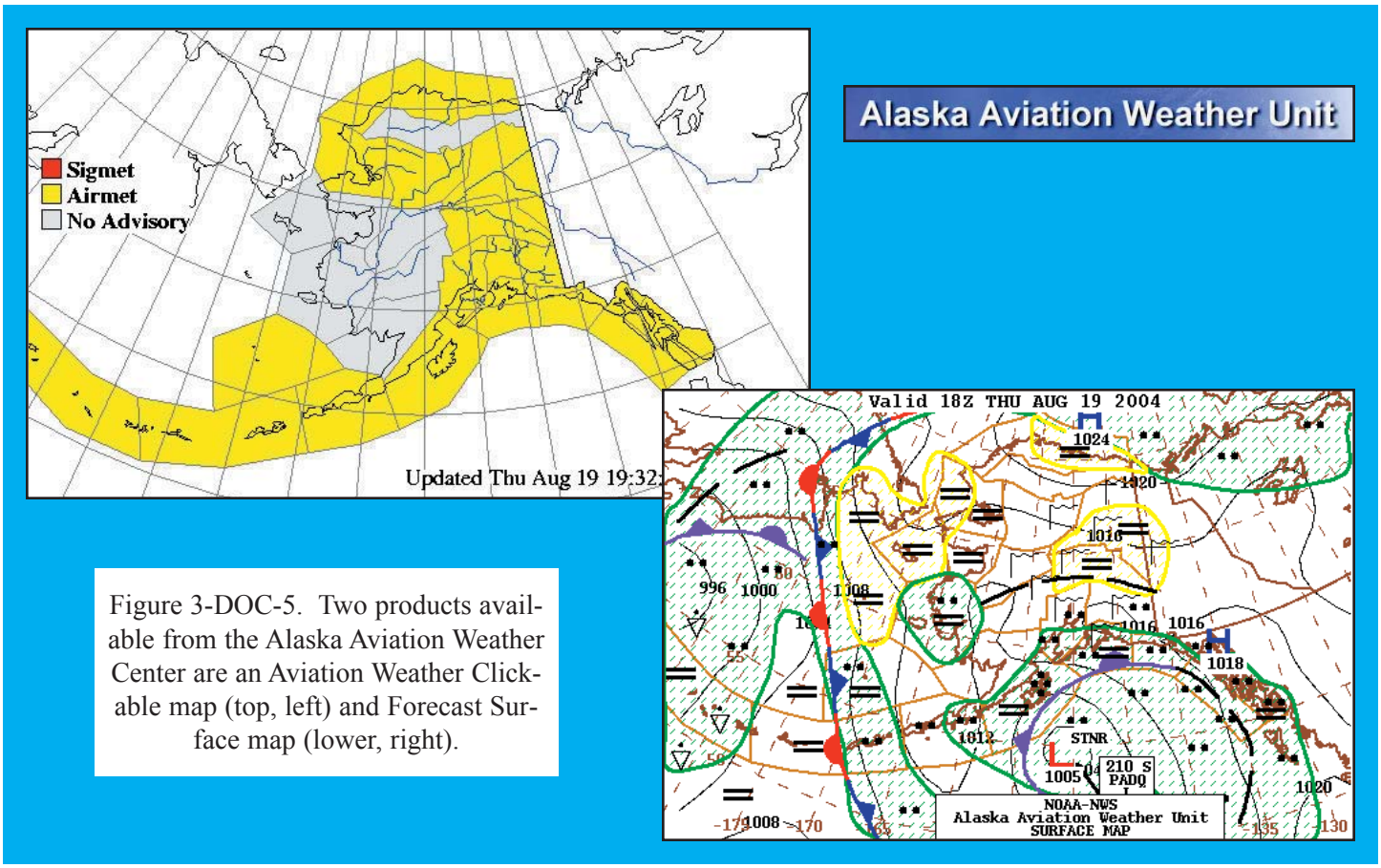


Figure 3-DOC-5. Two products available from the Alaska Aviation Weather Center are an Aviation Weather Clickable map (top, left) and Forecast Surface map (lower, right).

casts for flight planning and enroute aircraft operations for Alaska and surrounding areas (Figure 3-DOC-5).

WFO Honolulu/Central Pacific Hurricane Center. WFO Honolulu/Central Pacific Hurricane Center (CPHC) provides products in aviation, marine, and tropical cyclone areas. In aviation, WFO Honolulu provides wind, temperature, and flight hazards (e.g., icing, turbulence) forecasts for flight planning and enroute aircraft operations for the central north Pacific from 140 degrees W to 160 degrees E longitude and in the Oakland Flight Information Region south of 30 degrees N latitude through ICAO international agreement. The office handles international meteorological obligations to marine interests under the International Convention for Safety of Life at Sea (SOLAS). WFO Honolulu provides weather and sea state warnings and forecasts for the high seas of the central north and south Pacific south of 30 degrees N latitude. CPHC issues tropical cyclone advisories, forecasts, watches, and warnings for the central north Pacific including Hawaii.

SUPPORTING RESEARCH

The NWS conducts applied research, building upon the more basic research conducted by NOAA laboratories and the academic community. Applied meteorological and hydrological research is integral to providing more timely and accurate weather, water, and climate services to the public.

METEOROLOGICAL RESEARCH

The NWS conducts meteorological research to develop, test, evaluate, and improve numerical models and analysis/forecast techniques for weather and climate prediction including:

- Techniques for predicting mesoscale phenomena (e.g., heavy precipitation, tornadoes, and severe thunderstorms).
- Models to improve hurricane tracking, hurricane probability estimates, and tropical analyses.
- Storm surge models to assist in developing hurricane evacuation plans for additional coastal basins.
- Techniques to improve prediction of seasonal to interannual climate variability and their impacts on weather variability.

HYDROLOGIC RESEARCH

The NWS develops, implements and operationally supports improved hydrologic, hydraulic and hydrometeorological models and manages hydrologic data and enhanced quality control procedure to support national flood and water resources forecasting. Research encompasses the following areas:

- Improvements to the Ensemble Streamflow Prediction (ESP) system and its complementary models in the NWS River Forecasting System. Research, development and implementation of improved ESP procedures which improve forecast accuracy and quantify uncertainty at all time scales.
- Specialized flood and flash flood forecasting procedures using linked

hydrologic, hydraulic and meteorological models. Major research areas include developing distributed hydrologic models that use high resolution precipitation data from the NWS radar network, improvement of cold region processes in watershed models, and assimilation of data to improve initial conditions. Highly specialized hydraulic models for routing river flows will also provide information for generating maps of inundated areas.

• Development of improved multisensor precipitation estimates for input estimates for input into operational hydrologic and atmospheric models. Radar, rain gauge and satellite rainfall estimates are merged to produce optimum rainfall analyses.

• Development of verification methods to assess the added-value of new science and technology to the customer.

SPACE WEATHER RESEARCH

Research and development at SEC emphasizes understanding of the fundamental physical processes governing the regime from the solar surface, through the interplanetary medium, into the magnetospheric-ionospheric regions, and ending in Earth's upper atmosphere. These processes are manifest in the climatology and disturbances of Earth's magnetic field, the ionosphere, the charged particle populations at satellite orbits, and the atmospheric density at high altitudes (including low-Earth orbit). This applied research is focused on areas where advanced applications can be devised and prototyped to improve the specification and forecast of conditions in the space environment by developing and implementing models and indices, as well as by obtaining and processing new observations.

• Developing of the first dynamic, global ionospheric model to use ensemble Kalman filter techniques to assimilate data every 15 minutes. Disparate data from widely dispersed sources will enable the model output to be useful to radio-communicators and Global Positioning System (GPS) and Loran users.

• Developing of models to characterize and predict geomagnetic storm intensity development, spatially and temporally.

SUPPORT FOR COLLABORATIVE RESEARCH WITH THE ACADEMIC COMMUNITY AND OTHER PARTNERS

The Collaborative Science, Technology, and Applied Research (CSTAR) program was established to bring NWS-supported collaborative activities with the academic community into a structured program and to create a cost-effective transition from basic and applied research to operations and services. The CSTAR Program issues requests for proposals through which colleges and universities compete for 1-3 years of research funding. CSTAR supports shorter-term research activities with colleges and universities through the NWS/Cooperative Program for Operational Meteorology, Education, and Training (COMET) Outreach Program. The NWS also funds specific applied research grants and cooperative agreements directly in support of hydrology and meteorology research needs.

TRAINING

NOAA's NWS provides training to its workforce to enhance the professional and scientific development of its staff in support of NOAA's NWS mission and strategic goals. Training deficiencies and requirements are identified and addressed via the National Strategic Training and Education Plan (NSTEP) process, described in NWS Instruction 20-102 and available at http://www.nws.noaa.gov/directives/020/pd02001002a.pdf.

Training is provided through a variety of in-residence courses and distance learning techniques. Hands-on, in-residence training can be acquired at any of the three NOAA's NWS professional training facilities. The NWS Training Center (NWSTC) in Kansas City, Missouri, provides technical, meteorological and hydrologic, and management/leadership training. The Warning Decision Training Branch (WDTB) in Norman, Oklahoma, conducts situational awareness and remote sensing training with modules that integrate data for improving the warning decision process. Finally, the Cooperative Program for Operational Meteorology, Education and Training (COMET) in Boulder, Colorado, offers advanced meteorological and hydrometeorological education to ensure that NWS employees have access to the latest software and hardware to improve forecasting techniques. All three facilities also offer distance learning, Internet modules, teletraining, webcasts and CD-ROM based training. NWS employees have direct access to scientific and managerial training materials through the DoC/NOAA Learning Management System (LMS).

The NWSTC, in addition to providing scientific and technical training, is working to expand its leadership training and development skills through NOAA's NWS Leadership Academy. The goal of the Leadership Academy is to enable NWS and NOAA employees to become world-class leaders. The Academy is founded on a sequential and progressive approach designed to develop professional skills and capabilities to improve employee performance. From entry into the agency to senior career status, employees can take advantage of courses and processes that are part of a powerful management and leadership learning environment. Finally, NOAA's NWS is working to develop an organized curriculum to supply the necessary knowledge, skills, and abilities for all positions.

NATIONAL ENVIRONMENTAL SATELLITE, DATA, AND INFORMATION SERVICE

The National Environmental Satellite, Data, and Information Service (NESDIS), part of the National Oceanic and Atmospheric Administration (NOAA), manages the U.S. civil operational environmental satellite systems, as well as the three NOAA National Data Centers (NNDCs) that develop global, national, and regional databases to support meteorology, oceanography, geophysics, and the space environment. From these sources, NESDIS develops and distributes environmental data and information products and services critical to the protection of life and property, the national economy, energy development and distribution, global food supplies, and the development and management of environmental resources.

NESDIS was established as a NOAA line office on December 1, 1982. The merger of the former National Environmental Satellite Service (NESS) and the Environmental Data and Information Service (EDIS) formed NESDIS.

NESDIS procures, launches, and operates two types of satellites to provide worldwide environmental data and information products and services to Federal agencies, state and local governments, and private users. These satellite types are the Polar-orbiting Operational Environmental Satellite (POES) and Geostationary Operational Environmental Satellites (GOES).

The POES satellites are circling the Earth in an almost north-south orbit, passing close to both poles. These orbits have an altitude between 830 km (morning orbit) and 870 km (afternoon orbit), and are sun synchronous. One satellite crosses the equator at 10:00 A.M. local time, the other at 2:00 P.M. local time. Operating as a pair, these satellites ensure that data for any region of the Earth are no more than six hours old. Each satellite orbits the Earth 14 times per day, collecting global data for atmospheric and surface measurements in support of short-term weather forecasting and long-term global climate change research. NOAA also manages the command, control, and communications function of the Department of Defense's

(DOD's) Defense Meteorological Satellite Program (DMSP) constellations.

Currently NESDIS is operating six polar orbiters. The newest series of POES satellites began with the launch of NOAA-15 in May 1998, followed by NOAA-16 on September 21, 2000, NOAA-17 on June 24, 2002, and finally NOAA-18 on May 20, 2005. NOAA-17 and NOAA-18 are classified as the primary operational satellites. The NOAA-12, NOAA-14, NOAA-15, and NOAA-16 satellites continue to transmit data as stand-by satellites. NOAA-17 serves as the primary morning satellite and NOAA-18 the primary afternoon satellite.

An agreement with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) gives EUMETSAT responsibility for the morning segment of NOAA's polar environmental mission (circa 9:30 A.M. LST), with U.S.-provided payload instruments and sensors, beginning in 2006. Upon inception of this operational arrangement, NOAA will operate the afternoon mission while EUMETSAT will support the morning mission. Under this joint mission, upgraded instruments will be flown that will result in improvements for the user community. For example, the HIRS instrument will be upgraded resulting in improved atmospheric sounding information. AVHRR global one-kilometer data will be available enhancing the usefulness of this data for fire detection, CoastWatch, and any other applications that require higher resolution. It also provides the opportunity to use new sensor data from EUMETSAT instruments, in preparation for future NPOESS support

The National Polar-orbiting Operational Environmental Satellite System (NPOESS), the next generation of polar-orbiting satellites, will provide standard meteorological, oceanographic, environmental, and climatic information as well as space environmental remote sensing information. NPOESS will also continue to provide surface data collection and search and rescue capability. The NPOESS IPO, in consultation with the POES and DMSP program offices, is also studying additional potential cost effective approaches to maximize user satisfaction during the transition to NPOESS while guaranteeing continued non-interrupted data services. The first NPOESS launch is planned for 2013.

NESDIS is also responsible for operating two geostationary satellites, referred to as GOES East and GOES West, plus an on-orbit spare satellite. Each satellite views nearly one third of the Earth's surface. The GOES-12 (East) satellite is positioned at 75

degrees W longitude and the equator and monitors North and South America and most of the Atlantic Ocean. GOES-11 (West) is positioned at 135 degrees W longitude at the equator and monitors North America and the Pacific Ocean basin. These two satellites operate together to provide continuous monitoring necessary for effective and extensive weather forecasting, prediction, and environmental monitoring. GOES East and West circle the Earth in a geosynchronous orbit, which means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. This allows them to continuously view one part of the Earth's surface. The geosynchronous orbit is about 35,800 km (22,300 miles) above the Earth's equator.

On May 24, 2006, GOES-13 was launched. This spacecraft is the first spacecraft of the GOES N-P series. This new series improves NOAA's coverage during spacecraft eclipse season. After checkout of the satellite, GOES-13 will be available as a replacement for GOES East or West in the event of a failure. With the transition of GOES-11 to GOES West, GOES-10 will be repositioned to support South America as part of the Global Earth Observation System of Systems (GEOSS).

ENVIRONMENTAL SATELLITE SERVICES

OFFICE OF SATELLITE OPERATIONS

The Office of Satellite Operations (OSO) directs the operation of NOAA's environmental satellites and the acquisition of remotely sensed environmental data. It manages the Satellite Operations Control Center (SOCC) in Maryland, and two Command and Data Acquisition (CDA) stations (Fairbanks, Alaska, and Wallops, Virginia), which command, control, track, and acquire data from environmental satellites. The status of NOAA's satellites can be found on OSO's website (http://www.oso.noaa.gov/).

OSO also performs the command, control, and communications function of the Department of Defense's (DOD's) Defense Meteorological Satellite Program (DMSP) constellation. The mission of DMSP is to provide meteorological and special sensor data to users in support of worldwide DOD missions. DMSP is now operated from the SOCC at Suitland, Maryland. SOCC is the primary center for normal operations, mission planning, engineering, launch and early orbit support, and anomaly resolution.

OFFICE OF SATELLITE DATA PROCESSING AND DISTRIBUTION

The Office of Satellite Data Processing and Distribution (OSDPD) is responsible for the operations of NESDIS central ground data processing facilities. It processes and distributes data from NOAA and non-NOAA environmental satellites and generates automated and interpretive products for various government agencies, private industry, and educational institutions. Key customers include NOAA's National Weather Service (NWS), DOD, Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), worldwide Meteorological Watch Offices, Environmental Protection Agency (EPA), and state environmental protection agencies, foreign meteorological agencies, U.S. airlines, universities, and private sector companies. OSDPD exploits data from NOAA polar and geostationary environmental satellites, foreign (European, Japanese, and Indian) operational satellites, as well as domestic and foreign research satellites. The latter includes NASA's Tropical Rainfall Measuring Mission (TRMM), QuikSCAT, Earth Observing System satellites (including Aqua, Terra, and Aura missions), Japan's ADEOS-II, and DOD's WindSAT mission. OSDPD products are used in real-time in the production of forecasts and warnings of severe environmental events such as tornados, thunderstorms, flash floods, and hurricanes. Some OSDPD products, such as calibrated radiances from polar-orbiting sounders, vertical temperature and moisture profiles, cloud tracked wind speed and direction, and snow cover, are routinely integrated into numerical weather prediction forecast models on a global scale. These products often provide key model input parameters where routine in-situ measurements are not available.

OSDPD satellite products are distributed to a diverse user community for a broad range of environmental applications. The operational satellite data distribution networks provide user access to real-time or near, real-time environmental data and information. Quality assurance procedures are used to systematically evaluate and characterize the satellite products and services. This applies to both the fully automated products such as remapped GOES channel imagery and geophysical parameters (e.g., vertical wind profiles, bulk moisture and atmospheric stability indices, etc.) and POES-derived parameters (e.g., channel brightness temperatures, precipitation estimates, vegetation indices, sea surface temperature, temperature and moisture profiles, etc.), as well as to the value-added interpretive or analyzed products used to support disaster mitigation and warning services for various Federal agencies and the international community. The latter category includes products such as tropical storm position and intensity, fire locations and associated smoke extent, quantitative precipitation estimates for flash flood warnings, and volcanic ash plume extent and height. OSDPD works closely with its partners in the customer-supplier chain to ensure the most effective and timely implementa-

tion of its satellite data products and services. Working with NESDIS research organizations, such as the Office of Research and Applications (STAR) on the supplier side, and with government (primarily NWS), educational, and other organizations on the customer side, new and enhanced product generation algorithms are tested, evaluated, and implemented when deemed sufficiently validated and operationally useful. In partnership with other agencies and internal NESDIS organizations, new technologies are investigated and periodically deployed to satisfy emerging user requirements.

OSDPD distributes these environmental satellite products to NWS Advanced Weather Interactive Processing System (AWIPS), National Centers for Environmental Prediction (NCEP), Weather Forecast Offices (WFOs), and other Federal, state, and private sector organizations. This is done through dedicated satellite processing and server configurations or through the NOAAPORT satellite point-to-multi-point broadcast facility. The satellite data and products transmitted via NOAAPORT include remapped imagery, satellite precipitation estimates, high-density wind direction and speed projections at various atmospheric levels, GOES satellite imagery, and volcanic ash advisory messages. Over 100 universities receive satellite data and products supplied via NOAAPORT. NOAAPORT also delivers GOES and POES products in near, real-time to the AWIPS.

AWIPS is the NWS display and analysis workstation used in NWS national centers and field sites to integrate and display satellite data, model output, in-situ observations, and radar and wind profiles used in the production of hydro-meteorological analyses and forecasts. In addition, OSDPD serves NCEP as a backup for NOAA GOES data via the Man Computer Interactive Data Access System (McIDAS) and as a primary source to NCEP of NOAA POES and non-NOAA geostationary satellite data.

OSDPD also uses various websites to disseminate satellite data and products. For example, one site (http://www.ssd.noaa.gov) provides information and products on a multitude of OSDPD operational product areas including: worldwide tropical cyclone analyses, volcanic ash analyses, heavy precipitation analyses, snow/ice cover, and smoke and fire analyses. High quality imagery and derived products are extremely popular during hurricane season. Another OSDPD website (http://www.osei.noaa.gov) provides satellite imagery of significant environmental events such as oil spills, icebergs, hurricanes, and fires. Satellite data in digital scientific format are also available at ftp://gp16.ssd.nesdis.noaa.gov/, and several data sets are made available in Geographic Information System (GIS) format through http://www.gis.ssd.nesdis.noaa.gov/. A variety of geophysical products derived from both NOAA and non-NOAA polar orbiting platforms can be found at http://www.osdpd.noaa.gov/PSB/PSB.html.

OSDPD continues to support COSPAS-SARSAT, the international search and rescue program through provision of satellites, ground stations, and alert data distribution services. In 2005, COSPAS-SARSAT contributed to the rescue of 222 people in the U.S., bringing the worldwide total to over 18,500 rescues since its inception in 1982. In the COSPAS-SARSAT program, Russia, the U.S., India, France, and Canada provide the space segment, and 31 other countries provide ground systems to relay distress alerts and participate in the management of the program. NESDIS operates and maintains the U.S. SARSAT Mission Control Center and 12 Local User Terminals as ground stations.

The Local User Terminals receive 121.5/243/406 MHz emergency beacon signals directly from the satellites and process the information to provide the location of distress transmissions. COSPAS-SARSAT will terminate satellite processing of 121.5/243 MHz signals beginning February 1, 2009. This decision was made in response to guidance from the International Civil Aviation Organization and the International Maritime Organization due to problems in this frequency band that cause poor accuracy and numerous false alerts, adversely impacting the effectiveness of lifesaving services. These two specialized agencies of the United Nations are respectively responsible for international aviation and maritime search and rescue standards. The use of new emergency beacons that can use the Global Positioning System (GPS) to provide an accurate position continues to increase. NESDIS, working with its partners in the U.S. Air Force, U.S. Coast Guard, and NASA, is developing plans to augment the COSPAS-SARSAT System

with search and rescue instruments on future Global Positioning System (GPS) Block III satellites.

NATIONAL ICE CENTER

The U.S. National Ice Center (NIC), under the sponsorship of the U.S. Navy, NOAA, and the U.S. Coast Guard, is tasked with providing the highest quality operational global, regional, and tactical scale sea ice analyses and forecasts tailored to meet the requirements of U.S. national interests. NIC ice products are produced in a digital geospatial intelligence environment using data from polar orbiting satellites, ship/shore station reports, drifting buoys, meteorological guidance products, ice model predictions, and data from other government partners including foreign ice services. Primary remotely sensed data sources used for global and regional ice mapping include visible and infrared imagery from the POES imager, AVHRR (1.1 km spatial resolution), and the DMSP Operational Linescan System (0.55 km spatial resolution). NIC also uses passive microwave sensor data from the Special Sensor Microwave Imager (SSM/I), the Advanced Microwave Scanning Radiometer (AMSR-E), and WindSat processed using CAL/VAL, NASA Team 2, and Bootstrap sea ice concentration algorithms. These algorithms produce 25 km gridded mosaic ice maps that are instrumental in the production of NIC weekly composite Arctic/Antarctic ice maps, particularly over areas of extensive cloud cover. Higher resolution ice analysis products, used to ensure the safety of navigation and protect life and property at sea, are available from active microwave sensors such as the SeaWinds scatterometer aboard QuikSCAT and Synthetic Aperture Radar (SAR) instruments aboard the Canadian RADARSAT-1 and the European Envisat satellites. When available, SAR data are the source of choice for sea ice analysis. Most of the SAR imagery available to NIC is RADARSAT-1 ScanSAR wide mode that provides a 500 km wide swath with 100 m spatial resolution. These images are processed at four different ground stations and transferred to NIC via dedicated communication lines or via the Internet within six hours of acquisition. The NIC Science Team, supported by the NESDIS Center for Satellite Applications and Research (STAR), assists in the transition of pertinent scientific research to operations. This includes the transition of new real-time passive and active microwave sea ice products to the NIC operations floor, conducting an evaluation of current sea ice algorithms, and the use of satellite and in-situ data for initializing and evaluating the Polar Ice Prediction System (PIPS) version 3.0.

Routine NIC ice guidance products include regional-scale ice maps, annotated satellite imagery, short and long-term ice forecasts, and legacy ice information and ice climatology. Specialized support services include specific regional support, ship route recommendations, pre-sail ship briefings, aerial ice reconnaissance, and ship rider support. Specific sea ice features analyzed include ice edge position, ice concentration, ice thickness, form or floe size, ice motion, areas of compression and heavy surface deformation, and the location/orientation of open water or thin ice-covered leads.

Ice products are disseminated via the Internet (www.natice.noaa.gov) as simple electronic charts in Joint Photographic Experts Group (JPEG format), GeoTiff, and other GIS-compatible formats consistent with the World Meteorological Organization (WMO) digital standard for Sea Ice in GRIDDED (SIGRID-3) format. The date and time of data acquisition as well as the percentage of each data type used in all ice analyses are documented in a meta-data narrative.

Another NIC responsibility is oversight of the U.S. Interagency Arctic Buoy Program (USIABP). The USIABP was established in 1992, to provide the management structure and coordination necessary to maintain a baseline network of drifting buoys. Buoys within the array provide sufficient spatial resolution to define surface synoptic scale atmospheric pressure, air temperature, and sea-ice drift fields. Data are used in real-time for operational weather and ice forecasting and for research in the Global Climate Change Program. The USIABP is a collaborative program that draws operating funds and services from the collective contributions of government agencies and/or programs. These organizations include: the Naval Oceanographic Office, Office of Naval Research (ONR), NASA, National Science Foundation (NSF), and NESDIS, Office of Oceanic and Atmospheric Research (OAR), and the Office of Global Programs (OGP).

CENTER FOR SATELLITE APPLICATIONS AND RESEARCH (STAR)

STAR is the science arm of NESDIS. The mission of STAR is to transfer satellite observations of the land, atmosphere, ocean, and climate from scientific research and development into routine operations, and offer state-of-the-art data, products and services to decision-makers. STAR is an operations-driven research and development center, tuned to the needs of the nation's users of satellite data products. STAR conducts diverse research on satellite remote sensing, including the study of atmospheric, oceanic, and land processes. STAR participates in the life cycle of all operational NOAA satellites-from defining the initial requirements for a satellite mission, through calibration and application of the data after the satellite is in orbit, to development of products from the data, to final archiving and even reprocessing of data. STAR also works with data from non-NOAA satellites as

well, for research, to transfer capabilities to NOAA, and to obtain even more observations of the Earth than what is available from NOAA satellites.

STAR is a leader in planning future satellite observing systems to enhance the nation's ability to remotely monitor the environment. STAR also calibrates the Earth-observing instruments of all NOAA satellites to provide reliable measurements. STAR investigates how to develop satellite data sets that can be used in the following ways:

- Assess the current conditions on the Earth in a timely manner,
- Predict changes in the current conditions, and
- Study long-term trends in the environment.

NOAA's mission includes providing information, forecasts, advisories, and warnings on the earth's atmosphere, land, and ocean. STAR develops the techniques to obtain the necessary information from satellite data. STAR also supports the NOAA mission by providing scientific services to the users of NOAA satellites:

- Planning new satellites and sensors that monitor the environment,
- Collecting and processing data from environmental satellites,
- Building quality and reliability into NOAA satellite data, and
- Providing satellite products that NOAA can use to accomplish its mission.

STAR will create new products for monitoring atmospheric, oceanic, and environmental hazards; enhance NOAA's infrastructure for remote sensing; reduce the risk of launching new, untested, and very expensive satellites and sensors; expand its support to users (for example, expanding the NOAA CoastWatch Program into a global OceanWatch); and train users of STAR products and applications.

THE JOINT CENTER FOR SATELLITE DATA ASSIMILATION (JCSDA)

The JCSDA is a geographically distributed center operated as a partnership between NOAA, NASA, the U.S. Navy, and the U.S. Air Force. This cooperative arrangement allows NOAA, NASA, and DOD to take advantage of their combined science and technology resources in order to accelerate and optimize the use of existing and new satellite data for numerical weather prediction (NWP).

The JCSDA provides a focal point for cooperative research and development of common modeling and data assimilation infrastructure among its partners. As a result of its collaborative nature, the JCSDA will enable NOAA to improve NWP and climate prediction through the optimal use of data from existing satellites and to prepare for a large volume of new data from advanced satellite instruments, such as those on NPOESS, that will be launched during the next five to six years. These efforts will also help guide the selection and specification of future satellite instruments to ensure that the most effective observing system possible is created.

The JCSDA is tasked with developing new and powerful techniques to assimilate data into NWP and ocean, climate, and air quality analyses and models. This center is also tasked with reducing the time elapsed from satellite launch to operational data use from two years to one year. JCSDA activities directly support the missions of NASA, NOAA, and the DOD as well as those of organizations who contribute to or rely on NOAA's environmental assessment, prediction, and stewardship missions. In addition, through its partnership and coordination with DOD and other agencies, the JCSDA will enhance efforts to facilitate the transition from research into operations. Current projects focus on speeding available satellite data into operations and developing tools to support future assimilation projects. Six scientific priorities are being emphasized toward these ends:

- Development of a community-based radiative transfer model (CRTM): In the next few years, the accuracy and capability of the JCSDA CRTM will be significantly improved by including additional physical processes (e.g., atmospheric scattering), more efficient numerical techniques, and better surface emissivity models to allow more satellite data which is affected by surface to be properly assimilated.
- Development of data thinning and configuration technology and methodology: This allows faster and efficient delivery of advanced satellite data to major NWP centers globally.
- Advanced techniques to assimilate satellite data in cloudy and precipitation regions: Improving radiative transfer models and NWP cloud prediction schemes will significantly increase the fraction of satellite data being ingested into the assimilation systems and increase their impact.
- Improvement of the use of satellite land products in NWP models: For example, green vegetation fraction, snow cover, snow pack parameters, surface albedo, land, and sea surface temperature.
- Improvement of the use of satellite data in ocean data assimilation: This provides assimilated ocean data sets to

the community for research purposes and providing access to and support of an operational ocean data assimilation system.

• Assimilate satellite derived aerosol, ozone, and trace gas product: This will improve forecasts of visibility and health index with state-of-the-art air quality forecast models including chemical and biological process.

The JCSDA has additional long-term strategic goals. One is to accelerate the transfer of data assimilation research into operations by fostering common data assimilation code components, including techniques for specifying observation errors, background error co-variances, and data selection and reduction. Another is to foster development of a workforce capable of meeting the data assimilation challenges of future.

The JCSDA approach is bearing fruit. Recent accomplishments include:

• Improved radiative transfer techniques:

- CRTM was implemented operationally in the Global Data Assimilation System (GDAS).
- Improved microwave surface emissivity models leads to more AMSU-A data used over land, snow, ice.
- Vetted CRTM components are made available to partners and stakeholders via internet.

• Improved uses of current satellite data:

- More AMSU-A data are used over land, snow, and sea ice due to an improved surface emissivity model.
- Advanced data selection and assimilation techniques for infrared sounders increase use of AIRS data.
- NOAA-18 AMSU data is used operationally in NCEP GDAS.
- OMI Ozone data from TERRA satellite result in improved global ozone analysis.
- AIRS data used to predict NWP effectiveness of proposed designs for a future GOES-R sounder.

• More new satellite data tested for use in NCEP operational GDAS and forecast models:

- Techniques to assimilate GPS Radio Occultation data is developed, has been tested, and will improve NWP.
- WindSat ocean surface wind data was tested in the Global Forecast System with positive impact.
- JASON sea-surface altimetry data was tested in the Global Ocean Data Assimilation System.

POLAR SATELLITE PROGRAM

The primary mission of the Polar-orbiting Operational Environmental Satellite (POES) System is to provide daily global observations of weather patterns and environmental measurements of the Earth's atmosphere, its surface and cloud cover, and the proton and electron flux at satellite altitude. Since the beginning of the POES program, environmental data and products acquired by its satellites have been provided to users around the globe. These satellites increase the accuracy of weather forecasting by providing quantitative data required for improved numerical weather forecast models. Currently, the two primary operational spacecraft are NOAA-17 and NOAA-18.

NOAA polar satellites carry instruments that provide atmospheric temperature and moisture profiles. They also provide multi-channel images and carry a data collection and platform location system and a Search and Rescue Satellite-Aided Tracking (SARSAT) subsystem. The SARSAT subsystem is used to detect and locate distress alerts from maritime, aviation, and land-based users of emergency beacons operating at 121.5 or 243 or 406 MHz. In addition to taking thermal images of the Earth's surface and atmosphere, the NOAA polar-orbiting satellites carry sounder instruments to provide vertical profiles of atmospheric temperature and moisture.

POES satellites carry four primary instrument systems: the Advanced Very High Resolution Radiometer (AVHRR); the TIROS Operational Vertical Sounder (TOVS); the Space Environment Monitor (SEM); and the Solar Backscatter Ultra-Violet Instrument (SBUV/2). AVHRR provides data for real-time transmission to both Automatic Picture Transmission (APT) and High Resolution Picture Transmission (HRPT) users and for storage on the spacecraft tape recorders for later playback. The AVHRR/3 series of instruments, which began with NOAA-15, measures in six spectral channels (0.63, 0.86, 1.6, 3.75, 10.8 and 12 µm) with a nominal spatial resolution of 1.1 km and global resolution of roughly 4 km. Though the AVHRR/3 measures six channels, only five are transmitted in the data stream at any one time; the 1.6 and 3.75 m channels are time shared. The AVHRR/3 provides stored and direct-readout radiometer data for day and night cloud cover, sea surface temperatures, vegetation indices, fire detection, and snow and ice mapping. TOVS is comprised of the High-resolution Infrared Radiometer Sounder (HIRS) and the Advanced Microwave Sounding Unit (AMSU).

The HIRS/3 is a discrete-stepping, line scan instrument designed to measure scene radiance in 20 spectral bands to permit the calculation of the vertical temperature profile from Earth's surface to about 40 km. Multi-spectral data from one visible channel (0.69µm), seven shortwave channels (3.7 to 4.6µm), and twelve long wave channels (6.5 to 15µm) are obtained from a single telescope and rotating filter wheel containing twenty individual filters. An elliptical scan mirror provides cross-track scanning of 56 increments of 1.8µm. The mirror steps rapidly (<35 msec), then holds at each position while the 20 filter segments are sampled. This action takes place

every 100 msec. The instantaneous field of vision (FOV) for each channel is approximately 1.4 µm in the visible and shortwave IR and 1.3 µm in the long wave IR band that, from an altitude of 833 km, encompasses an area of 20.3 km and 18.9 km in diameter, respectively, at nadir on the Earth.

Each AMSU-A instrument is composed of two separate units: (1) AMSU-A2 with two channels at 23.8 and 31.4 GHz and (2) AMSU-A1 with twelve channels in the range of 50.3 to 57.3 GHz and one channel at 89.0 GHz. The AMSU-B has five channels with frequencies centered on 89, 150, 183±1, 183±3, and 183±7 GHz, respectively. AMSU-B, provided by the United Kingdom Meteorological Office, produces soundings of humidity from the surface to 200 millibars (mb). AMSU-A has a nominal FOV of 3.3 degrees (48 km on surface at nadir) and AMSU-B a field of view of 1.1 degrees (16 km on surface at nadir). AMSU-A (AMSU-B) samples 30 degrees (90 degrees) Earth views, covering ±48.95 degrees from the subsatellite point. In addition, the specialized 89 GHz channel, with the capability to see through high and mid-level clouds to low level precipitation producing clouds, is used to determine the position and structure of tropical cyclones on a global scale. The AMSU-A1 uses two antenna systems, providing observations in the twelve oxygen band channels (3-14) for retrieving the atmospheric temperature profile from the Earth's surface to about 42 km, or from 1000 to 2 mb. The remaining three channels (1 and 2 from A2 and 15 from A1) aid the retrieval of temperature soundings by correction of surface emissivity, atmospheric liquid water, and total precipitable water. These window channels also provide information on precipitation, sea ice, and snow coverage.

The Microwave Humidity Sounder (MHS) is a new instrument for the NOAA satellites. It is a five-channel microwave instrument intended primarily to measure profiles of atmospheric humidity. It is also sensitive to liquid water in clouds and so measures cloud liquid water content. Additionally, it provides qualitative estimates of the precipitation rate.

The SEM measures solar proton flux, alpha particle and electron flux density, and energy spectrum and total particulate energy distribution at spacecraft altitudes. The two sensors included within this instrument are the Total Energy Detector (TED) and the Medium Energy Proton and Electron Detector (MEPED), in addition to a common data processing unit. This instrument augments the measurements made by NOAA's geostationary satellites.

The NOAA-16, NOAA-17, and NOAA-18 POES carry the Solar Backscatter Ultraviolet Instrument (SBUV/2). The SBUV/2 instrument is a non-scanning (fixed nadir viewing) spectrometer designed to measure scene radiance and solar spectral irradiance from 160 nanometers to 400 nanometers. Data obtained from the instrument are used to compute the amount and vertical distribution of ozone in the Earth's atmosphere on the sunlit side of the Earth. Ozone evaluation, calibration, and validation activities took place for the new Solar Backscatter Ultraviolet Instrument (SBUV/2) with the launch and successful checkout of NOAA-17 & 18. A new ozone profile retrieval algorithm (Version 8) is under development at NASA. As soon as it becomes available, NOAA will begin to incorporate it in its SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-14, NOAA-16, NOAA-17, NOAA-18, and with the TOVS instruments on NOAA-14, NOAA-15, NOAA-16, NOAA-17, and NOAA-18. Experimental ozone products at high temporal resolution are also being produced from the GOES-8 sounder channels. Monitoring is limited to North America. Preliminary results show the GOES total ozone values are comparable to amounts from the Total Ozone Mapping Spectrometer and ground-based measurements.

The ground system required to receive large volumes of digital data from NOAA satellites consists of two major subsystems: the Polar Acquisition and Control Subsystem (PACS) and the Central Environmental Satellite Computer System (CEMSCS). The PACS includes the Wallops, Virginia, and Fairbanks, Alaska, Command and Data Acquisition (CDA) stations and the SOCC at Suitland, Maryland. All the CEMSCS components are in the NOAA facility at Suitland. PACS is used to command and control the spacecraft, monitor its health via housekeeping telemetry, and retrieve and transmit the spacecraft environmental data to the CEMSCS processing and data handling facility. The delivery of NOAA system data from the CDA to Suitland is accomplished by using the General Electric American Communications, Inc. commercial satellite communications network. This system, which includes Earth stations at Suitland, Wallops, and Fairbanks, delivers the data to SOCC. These data are immediately passed to the CEMSCS for processing. The CEMSCS ingests the raw satellite data and pre-processes and stores them along with appended auxiliary information, such as Earth location, calibration, and quality control parameters. The data processed by the CEMSCS are used for environmental products and operational weather predictions that are disseminated to users throughout the world.

The Argos Data Collection (and location) Service (DCS) operates on the NOAA Polar-orbiting Operational Environmental Satellite (POES) constellation and was established through a Memorandum of Understanding (MOU) with France in 1974, and

renewed in 1986. The lead agencies for this international cooperative agreement are NOAA and the Centre National d'Etudes Spatiales (CNES) for France. CNES provides for the development and delivery of the Argos DCS instrument. NOAA provides spacecraft integration/launch services, downloads stored mission data via NOAA Command Data Acquisition facilities, and provides pre-processed data delivery. Data post-processing and delivery to customers is the responsibility of CNES, which through a subsidiary maintains distribution centers located in Toulouse, France, and Largo, Maryland.

The Argos DCS is a space-based, data telemetry system that provides a global means to locate and collect environmental data from fixed and moving, low-power transmitters; i.e., polar ice buoys, ocean floats, birds, mammals, etc., in near, real-time (15 minutes to 3 hours). The Argos DCS transmits data for operational and research related environmental applications, e.g., meteorology, oceanography, and protection of the environment, with the majority of users being government/non-profit agencies and researchers. Argos DCS customers are engaged in over 1,000 programs operating approximately 15,000 data collection platforms in 72 countries.

The Argos DCS program will incorporate Argos instruments on other international satellite platforms as opportunities permit, such as the European Organization for Exploration of Meteorological Satellites (EUMETSAT) to fly Argos DCS on the METOP satellite series (2006-2020). Future instrument developments include the incorporation of a downlink message capability, scheduled to fly on the Metop-A, NOAA-N' and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) constellation (2013-2026). This new capability, in response to customer requirements, will provide the opportunity for new and novel uses of the Argos DCS and allow the user to communicate with deployed platforms in the field.

GEOSTATIONARY SATELLITE PROGRAM

Two operational geostationary satellites, GOES-12 (75 degrees W) and GOES-11 (135 degrees W), provide coverage of virtually the entire western hemisphere for operational environmental sensing of the Earth. GOES-13, formerly GOES-N, was launched on May 24, 2006. After a successful checkout, GOES-13 will be stored in orbit at 105 degrees W. GOES-10 (formerly GOES West) was replaced by GOES-11 and, at the conclusion of GOES-13 checkout, will transition to serve South America in support of NOAA, the Comisión Nacional de Activades Espaciales, and the World Meteorological Organization (WMO) agreement. The shift of GOES-10 will help protect lives and property in North, Central, and South America by significantly improving satellite detection of severe storms, floods, drought, landslides, volcanic ash clouds, and wildfires. The shift will further strengthen the WMO's World Weather Watch Global Observing System. It will allow for improved prediction, response and follow-up and expanded understanding of how our Earth system works. The projected launch schedule and associated instruments for geostationary satellites are shown in Table 3.1. It should be noted that current plans as of mid 2006 call for GOES-13 to be placed in storage once checkout is completed late 2006. GOES-11 replaced GOES-10 in the west in June 2006 and GOES-12 to remain in the east. GOES-10 will be moved to 60 degrees West in late 2006, to support the Earth Observation Partnership of Americas (EOPA) program which is part of the GEO program.

The GOES satellites host an imager capable of detecting atmospheric, sea surface, and land properties in five spectral bands including the 3.9 µm and 13.35 µm wavelengths. Beginning with GOES-12, the 12.0 µm channel was replaced with a 13.35 µm channel, with the goal of achieving more accurate cloud height assignments for mid- and upper-level atmospheric satellite wind-velocity estimates. This trade-off notably impacts the sea-surface temperature retrievals by eliminating the capability for daytime split-window retrievals, increasing the rms error by about 0.5 C. Also, the spatial resolution of the water vapor channel is improved to 4 km from 8 km.

GOES satellites transmit all five spectral bands simultaneously, providing the user community with continuous views of atmospheric measurements in various wavelengths, each with its own atmospheric, land, and ocean application. GOES spacecraft were designed for flexible scanning of the Earth; a variety of scans or sector coverage can be scheduled. For example, the full-Earth disk is normally scanned once every 3 hours and requires about 30 minutes to complete the entire scan. Depending on requirements to monitor environmental hazards on the Earth's surface or in the atmosphere, 30-minute periods in between the full-disk scans may be scheduled as a mixture of 15-minute intervals (routine operations) or 7.5-minute interval (severe storm operations) rapid scans over the contiguous US. To further support mesoscale and microscale analyses, 1000 km x 1000 km areas can also be scanned at 1-minute intervals, to capture rapidly developing and dynamic environmental phenomena..

For GOES 11, the five channels and respective resolutions are as follows:

- Channel 1 (Visible, .55 m to .75 m) 1 km.
- Channel 2 (Infrared, 3.8 m to 4.0 m) 4 km.
- Channel 3 (Water Vapor, 6.5 m to 7.0 m) 8 km.

TABLE 3.1 PROJECTED SATELLITE LAUNCH SCHEDULE

POLAR-ORBITING SYSTEM

Satellite Designator	Planned Launch Date*
NOAA-N	CY 2005
METOP-2	CY 2010
NPP	CY 2010
NOAA-N'	CY 2007
NPOESS-C1	CY 2013
METOP-1	CY 2006
NPOESS-C2	CY 2016
NPOESS-C3	CY 2018
METOP-3	CY 2015
NPOESS-C4	CY 2020

GEOSTATIONARY SYSTEM

Satellite Designator	Planned Launch Date*
GOES N	CY 2006
GOES O	CY 2008
GOES P	CY 2009
GOES Q	Cancelled
GOES R	CY 2012
GOES S	CY 2014
MTSAT-1R	CY 2005

*Launch date depends on performance of prior spacecraft and is subject to change.

NOAA Instruments for NOAA Polar-Orbiter and METOP Series

AVHRR - Advanced Very High Resolution Radiometer
SEM - Space Environment Monitor
SBUV - Solar Backscatter Ultraviolet Instrument (NOAA PM mission only)
HIRS - High Resolution Infrared Sounder
DCS ARGOS - Data Collection System
AMSU-A - Advanced Microwave Sounding Unit-A
AMSU-B - Advanced Microwave Sounding Unit-B
SARP - Search and Rescue Processor
SARR - Search and Rescue Repeater
MHS - Microwave Humidity Sounder (NOAA-N/N' and METOP)

Instruments for NPOESS Series

VIIRS - Visible/Infrared Imager/Radiometer Suite
Microwave Imager/Sounder (to be determined by new competition for C2)
CrIS - Cross-track Infrared Sounder
ATMS - Advanced Technology Microwave Sounder
OMPS - Ozone Mapper/Profiler Suite -Nadir
A/DCS - Advanced Data Collection System
SARSAT - Search and Rescue Satellite-Aided Tracking System
CERES - Cloud and Earth Radiant Energy System (to be flown on C1 only)
SEM - Space Environment Monitor

Instruments for GOES-R+ Series

Advanced baseline Imager (ABI)
Hyperspectral Environmental Suite (HES)
Solar Instrument Suite (SEI)
Space Environment In-Situ Suite (SEISS)
Geostationary Lightning Mapper (GLM)

EUMETSAT Unique Instruments for METOP Series Satellites

ASCAT - Advanced Scatterometer
GOME - Global Ozone Monitoring Experiment
GRAS - GPS Receiver for Atmospheric Sounding
IASI - Infrared Atmospheric Sounding Interferometer

• Channel 4 (Infrared, 10.2 m to 11.2 m) 4 km.

• Channel 5 (Infrared, 11.5 m to 12.5 m) 4 km.

For GOES-12/13, the five channels and respective resolutions are as follows:

• Channel 1 (Visible, .52 m to .71 m) 1 km.

• Channel 2 (Infrared, 3.73 m to 4.07 m) 4 km.

• Channel 3 (Infrared, 13.0 m to 13.7 m) 8 km (4 km starting with GOES O-P).

• Channel 4 (Infrared, 10.2 m to 11.2 m) 4 km.

• Channel 5 (Water Vapor, 5.8 m to 7.3 m) 4 km.

The GOES sounder instruments, consisting of 19 spectral channels, are used for measurements of atmospheric temperature and moisture profiles, surface and cloud top temperatures, and ozone distribution. Products derived from the sounder include precipitable water and lifted index - a measurement of atmospheric stability. Comparable to the imager, the sounder is capable of providing various scan coverage, such as full Earth imagery, sectored imagery, and local imagery. In routine operations, GOES-12 and GOES-11 provide hourly sounding coverage.

The GOES Space Environment Monitor (SEM) collects data for warnings of solar activity. This block of instruments is more extensive than on POES. The GOES SEM instruments include X-ray monitors that detect solar flares, energetic particle sensors, and three component vector magnetometers to measure changes in the ambient magnetic field. Real-time SEM data are used to support operational NOAA and DOD space environment forecasts and alerts. Data from GOES SEM sensors are archived by the National Geophysical Data Center and provided to retrospective users on line via Internet and on a variety of computer media.

Starting with GOES-12, a Solar X-Ray Instrument (SXI) is being flown that provides near, real-time X-ray images of the sun for ionospheric changes that affect radio communications and mangetospheric variations that induce currents in electrical power grids and long distance pipelines. Also, these conditions can cause navigational errors in magnetic guidance systems, introduce changes in spacecraft charging, produce high energy particles that can cause single event upsets in satellite circuitry, and expose astronauts to increased radiation. The SXI will observe solar flares, solar active regions, and coronal structures. Images from the SXI will be used by NOAA and U.S. Air Force forecasters to monitor solar conditions that affect space weather conditions, including the dynamic environment of energetic particles, solar wind streams, and coronal mass ejections emanating from the sun.

GOES also carries a Data Collection System (DCS), which is used to collect and relay environmental data observed by a variety of remotely located platforms, such as river and tide gauges, seismometers, buoys, ships, and automatic weather stations. In support of NOAA missions, GOES DCS data are used in weather forecasts and warnings, reservoir control, and flood monitoring. While the GOES DCS is a critical element for national and international meteorological and hydrological programs, the NWS NEXRAD program relies on the DCS data as a vital input for calibration and validation. Tsunami watches and warnings for the Pacific Ocean are prepared using the Data Collection Platform data transmitted via GOES DCS. The GOES DCS program touches all aspects of our lives in supporting water quality, air pollution, and global environmental monitoring.

The GOES Search and Rescue Satellite Aided Tracking (SARSAT) System is capable of providing an immediate distress alert, unlike the POES satellite SARSAT transponders which must come within line of site of a Local User Terminal, in order to relay the distress beacon back to the U.S. SARSAT Mission Control Center (USMCC). Newer state of the art COSPAS-SARSAT distress beacons, utilizing the Global Positioning System (GPS), now have the capability to provide location information in the distress message relayed by GOES to the USMCC.

NESDIS continues to improve user access to its operational satellite products and services using new communications technologies including the Internet. One important on-line access system, managed and operated by OSD is the Comprehensive Large-Array Data Stewardship System (CLASS). The CLASS (www.CLASS.noaa.gov) provides satellite data access, display, and electronic transfer. Available data types include AVHRR, ATOVS, DMSP (special sensor), and RADARSAT (authorized subscription users). While developed as an independent system, the Satellite Active Archive (SAA) serves as NOAA's initial interoperable interface to NASA's Earth Observing System Data and Information System (EOSDIS). After the phase out of the GOES TAP system in 1998, many users now rely on GOES sectorized images, mapped to standard AWIPS grids, available in near, real-time at *www.goes.noaa.gov.*

Near-real-time images and interpretive analyses of tropical storms and hurricanes worldwide, ash from volcanic eruptions within the western hemisphere, heavy precipitation in the U.S. which cause flash flooding or blizzards, wild fires and smoke within the US, and northern hemisphere snow boundaries are located at *www.ssd.noaa.gov*. Specially enhanced and annotated imagery and image loops of environmental events, such as flooding, hurricanes and other severe storms, volcanic eruptions,

fires, and dust storms are available from *www.osei.noaa.gov*. This web site was set up for use by the news media and general public, and to provide once or twice per day satellite views of an environmental event for Federal, state, and international governments and agencies. Also supporting the media, scientific organizations, and Federal and state agencies is a specially designed web site featuring visualizations of satellite data, found at www.nnvl.noaa.gov/.

INTERNATIONAL AND INTERAGENCY SUPPORT FOR DISASTER MANAGEMENT

International Charter

NOAA is a member of the International Charter for Space and Major Disasters. NOAA is represented on the Executive Secretariat and the Board of the International Charter and periodically serves as the lead agency providing secretariat services, policy leadership, and Charter activities coordination.

The International Charter aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through authorized users. Each member agency (the European Space Agency, France's Centre National d'Etudes Spatiales, the Indian Space Research Organisation (ISRO), NOAA, Argentina's Comisión Nacional de Actividades Espaciales, the Japan Aerospace Exploration Agency (JAXA), USGS, and DMC International Imaging) has committed resources to support the provisions of the Charter and thus is helping to mitigate the effects of disasters on human life and property. An authorized user can call a single number to request the mobilization of the space and associated ground resources of the six space agencies to obtain data and information on a disaster occurrence.

U.S. Interagency Collaboration

NOAA is a member of the U.S. Subcommittee on Disaster Reduction (SDR), which provides a unique Federal forum for information sharing; development of collaborative opportunities; formulation of science and technology based guidance for policy makers; and dialogue with the U.S. policy community to advance informed strategies for managing disaster risks. Last year, the SDR, through the President's National Science and Technology Council, released a report entitled "*Grand Challenges for Disaster Reduction*." This report identifies six grand challenges for disaster reduction and provides a framework for prioritizing related Federal investments in science and technology. In December 2005, the SDR released a joint report with the U.S. Group on Earth Observations, "*Tsunami Risk Reduction for the U.S.: A Framework for Action*." The plan places the President's initiative to improve domestic warning capabilities in the context of a broad national tsunami risk reduction effort and U.S. participation in international efforts to reduce tsunami risk worldwide.

SUPPORTING RESEARCH PROGRAMS

Recent advances in numerical weather prediction (NWP) models, both at NOAA's NCEP and other major International NWP Centers, require higher quality satellite-derived winds, particularly over the traditionally data void oceanic regions of the globe. The NESDIS GOES East and West wind processing suites are totally automated and use a series of geostationary satellite images to derive wind estimates. The automated winds algorithm uses an objective pattern matching technique to estimate velocity, and satellite water vapor and infrared brightness temperature data to assign heights to these derived wind estimates. The automated quality control of image registration is also an important component of the NESDIS GOES-East and West winds processing suite.

Approximately 20,000 cloud-drift and water vapor motion wind vectors are derived from both satellites for each cycle and distributed to EMC and to the Global Telecommunications System (GTS). EMC uses these operational NESDIS wind products in their global and regional data assimilation/numerical forecast systems. NESDIS recently completed the effort to reformat the winds in WMO-sanctioned BUFR format. Current work involves the investigation of a slow bias seen in water vapor winds.

The newest satellite wind products include the low-level high-density visible satellite winds. During the daylight hours, visible channel data can be used to track cloud motions. The GOES visible imagery offers high horizontal resolution (1 km) and frequent image sampling (15-30 minutes nominally; higher in special rapid scan modes). The visible channel can depict lower tropospheric cumuliform tracers in areas not covered by opaque cirrus. In terms of tropical cyclones, visible winds can depict the low level flow in the outer storm vortex region, which is an important area in assessing storm motion. The GOES satellites have an atmospheric sounder that includes two water vapor channels centered at 7.0 µm and 7.3 µm. These sounder channels can be employed as surrogate imagers to track water vapor features radiating from the lower layers of the troposphere. The weighting function of the 7.0 µm channel peaks around 450 mb and the weighting function of the 7.3 µm channel peaks around 550 mb. Water vapor winds generated from these two channels will compliment the imager-based cloud-drift and water vapor winds, resulting in an improved three-dimensional depiction of the wind field. The implementation of these new algorithms and the visible wind products into the operational environment at NESDIS began in 1999.

AVIATION

Aviation applications research focuses on detection and mitigation of hazards such as volcanic ash, in-flight icing, and fog and low ceilings. An encounter with an airborne volcanic ash cloud can result in millions of dollars in damage to jet engines and the airframe, as well as the risk of engine stalls. Therefore, avoiding these hazards is critical. Remote sensing is the primary means of identifying and tracking volcanic ash clouds. In-flight icing causes significant aerodynamic drag and 5-10 percent of all fatal air crashes for smaller, general aviation and commuter class aircraft. Fog and low ceilings are a major reason for aviation delays, resulting in >$2B annual economic loss, and account for about 25 percent of fatal aviation and maritime accidents.

ATMOSPHERIC MOISTURE AND STABILITY PRODUCTS

Research continues to improve the atmospheric moisture and stability products from the GOES East and GOES West sounder instruments. Precipitable water for three layers of the atmosphere (surface to 900 hPa; 900-700 hPa; and 700-300 hPa) are computed from the soundings. Total precipitable water (TPW) for the entire atmospheric column, from the Earth's surface to the top of the atmosphere, is also computed. These precipitable water products are particularly valuable for the short-term forecasting of precipitation-locating those environments favorable for heavy precipitation and flash floods, thunderstorms, and fog. Hourly updates of this data provide useful information for the EMC regional data assimilation systems and for weather forecasters in the field. EMC currently uses the GOES precipitable water retrievals as input to Eta Data Assimilation System (EDAS), which provides the initialization for the Eta forecast model. NESDIS is currently aiding EMC with running global and regional model impact analyses to improve and optimize the use of the GOES derived products in numerical weather prediction schemes.

As of July 8, 2003, the hourly cloud top information from the GOES sounder data is being assimilated into the operational National Centers for Environmental Prediction (NCEP) Eta Data Assimilation System (EDAS). The regional Eta model and the Rapid Update Cycle (RUC) model both assimilate GOES sounder cloud information to help improve the initial moisture and cloud field. In addition to the moisture products, numerous atmospheric stability indices can be computed from measurements made by the GOES sounder instrument. Two stability indices, the lifted index (LI) and CAPE index, are computed on a routine basis. Since these indices are produced hourly, sequential images of these derived quantities clearly show the diurnal and dynamic changes associated with weather events.

So, in addition to providing these data to EMC for use in numerical weather prediction models, the graphical representation of these products allows for the looping of the products in time. This capability aids NWS forecasters in the field to understand the time evolution of severe storms. For example, several (lifted index, total precipitable water, and cloud-top information, etc.) of these derived images are operational and sent to the NWS AWIPS (Advanced Weather Interactive Processing System) for forecaster use.

Because channel noise has improved with each successive sounder instrument, the GOES sounder moisture and stability products moved from a horizontal resolution of approximately 50 km to be approximately 10 km. The increased horizontal resolution offers exciting possibilities for enhanced use of these products in mesoscale forecasting. For example, the finer resolution improves the depiction of gradients in the retrieved products, such as moisture and atmospheric stability, which focuses attention to a local area of interest. These products can be viewed at http://www.orbit.nesdis.noaa.gov/smcd/opdb/goes/soundings/index.html#products and cimss.ssec.wisc.edu/goes/realtime. In addition, these products are available from GOES computer servers within OSDPD or at http://www.ssd.noaa.gov/PS/PCPN/pcpn-na.html#SNDR.

TROPICAL CYCLONE MONITORING

NESDIS continues to improve upon satellite-based techniques for estimating tropical cyclone positions and intensities, and for describing the internal structure of these storms. Recent sensors, such as AMSU and TRMM, among others, are being incorporated into the NESDIS operational tropical program, which supports the NWS and DOD hurricane programs. Real-time imagery and NESDIS tropical text messages can be viewed at www.ssd.noaa.gov/SSD/ML/real-time.html. Research is also being performed to improve the forecasts of tropical cyclone formation and intensity change by making better use of satellite observations.

PRECIPITATION ESTIMATES

Estimates of precipitation from satellites provide a valuable supplement to information from radar and rain gauges. This information is particularly useful for such phenomena as tropical systems that are still outside the radar umbrella. For monitoring of short-term rainfall events, the primary operational algorithm is the Hydro-Estimator (H-E), which provides estimates of instantaneous rain rate from GOES infrared data every 15 minutes over the CONUS and experimentally produces estimates worldwide. The H-E adjusts its computed rain rates for moisture availability, sub-cloud evaporation, orographic uplift, and other fac-

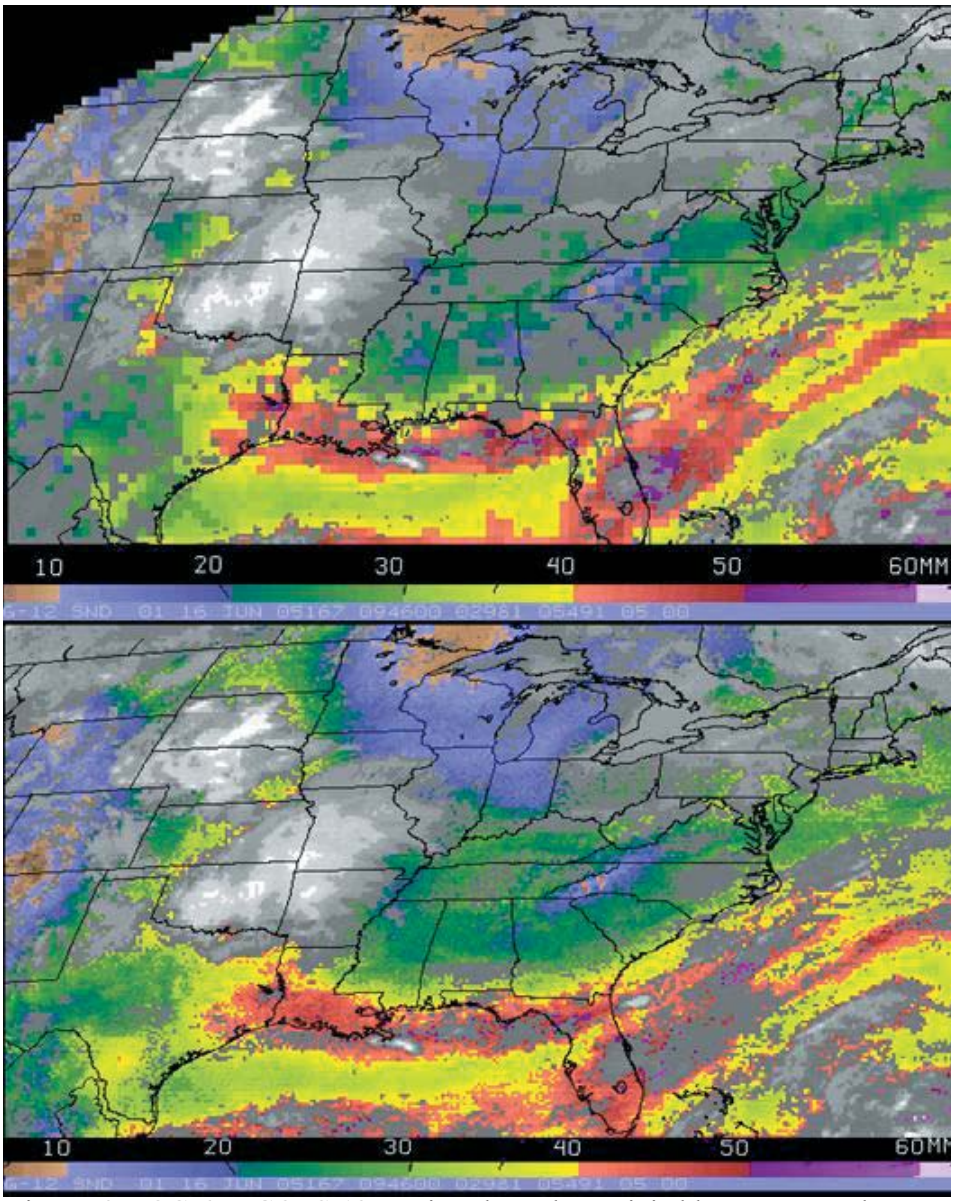


Figure 3-DOC-6. GOES-12 retrieved total precipitable water products at approximately 50 km resolution (top) and approximately 10 km resolution (bottom)

tors using data from operational numerical weather prediction models run at NCEP. Another algorithm approaching operational status is the GOES Multi-Spectral Rainfall Algorithm (GMSRA), which uses four of the five GOES Imager channels for more precise identification of raining areas. An experimental algorithm called the Self-Calibrating Multivariate Precipitation Retrieval (SCaMPR) attempts to combine the relative strengths of infrared-based and microwave-based precipitation algorithms to produce a more accurate result than could be achieved using GOES data alone. Real-time graphics of these and other algorithms plus real-time validation statistics are available at http://www.orbit.nesdis.noaa.gov /smcd/emb/ff/; in addition, the H-E is available to NWS field forecasters once per hour via AWIPS. In the near future, both the H-E and GMSRA will be available on AWIPS every 15 minutes, and coverage will be expanded to Hawaii and Puerto Rico.

In addition to short-term rainfall monitoring, longer-term precipitation analyses are created using microwave data from an improved AMSU-B/MHS algorithm and the AMSR-E. The AMSU-B/MHS products, which also include cloud properties and other related information, can be obtained at http://www.osdpd.noaa.gov/PSB/IMAGES/MSPPS_day2.html. These include estimates of equivalent snow water content and discrimination of falling rain from falling snow. Rainfall estimates from the DMSP SSM/I instrument also continue to be produced in cooperation with the U.S. Air Force and U.S. Navy and can be accessed at http://www.osdpd.noaa.gov/PSB/SHARED_PROCESSING/SHARED_PROCESSING.html.

These rainfall products are also used in direct forecasting applications. The Hydro-Nowcaster (H-N) extrapolates H-E estimates forward in time up to 3 hours based on storm cell movement, and the resulting 0-3 hour nowcasts are available at http://www.orbit.nesdis.noaa.gov/smcd/emb/ff/hn.html. Meanwhile, forecasts for 24-hour rainfall from tropical systems that are about to make landfall are produced operationally for the entire globe by extrapolating microwave-based estimates of rainfall from the (SSM/I, AMSU-B/MHS, or TRMM Microwave Imager) along the predicted storm track. These estimates are available at http://www.ssd.noaa.gov/PS/TROP/trap-img.html. Efforts are underway to produce an ensemble version of TRaP to enhance its accuracy and utility to forecasters.

MICROBURST PRODUCTS

Convective storms can pose serious threats to life and property. Of great concern are those storms that produce downbursts, defined as strong convective downdrafts that result in an outburst of damaging winds on or near the Earth's surface. In addition, downbursts are a hazard to aircraft in flight, especially during takeoff and landing phases. In order to assist the operational forecaster in the prediction of

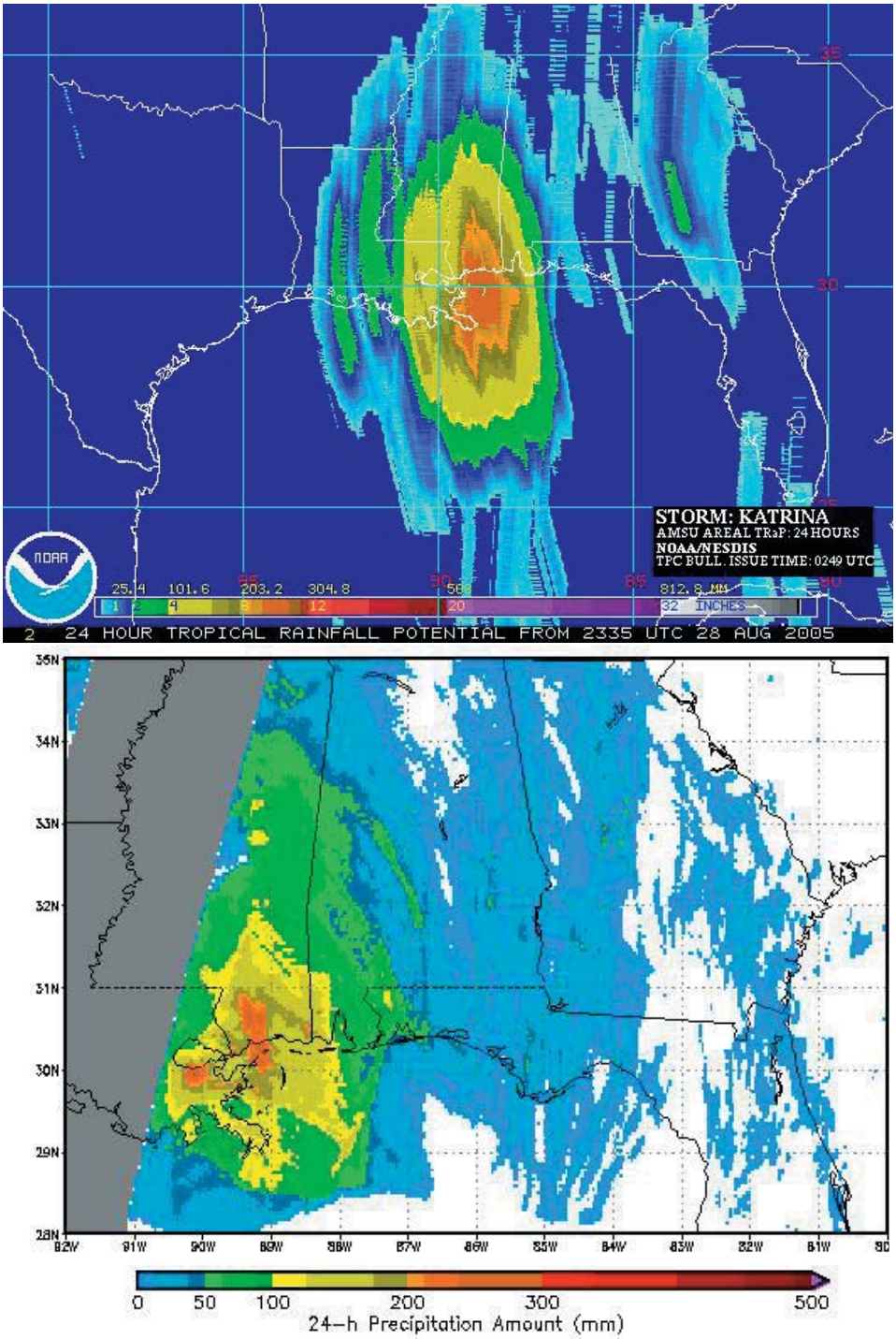


Figure 3-DOC-7. Tropical Rainfall Potential (TRaP) forecast for Hurricane Katrina (top) and corresponding Stage IV radar/rain gauge estimates (bottom) for the 24 hours ending 0000 UTC 30 August 2005. Data over the western portion of the Stage IV image are missing due to storm-related communications outages at the Lower Mississippi River Forecast Center (LMRFC) where that region's Stage IV estimates were produced.

this type of hazardous weather event, GOES sounder-derived microburst products have been developed and implemented. These sounder-derived products include the Wind Index (WINDEX) for estimating the magnitude of convective wind gusts, a Dry Microburst Index (DMI) for dry microburst potential, and Wet Microburst Severity Index (WMSI) for wet microburst potential.

The newest product of the suite, the Hybrid Microburst Index (HMI), indicates the potential for convective downbursts that develop in an intermediate environment between a wet type, associated with heavy precipitation, and a dry type associated with convection in which very little to no precipitation is observed at the surface. For more information visit http://www.orbit.nesdis.noaa.gov/star/Pryor_K.php.

AIRCRAFT ICING

Several upgrades to the GOES aircraft icing product have been implemented. New thresholds for the Band 2-4 (3.9-10.7 micrometer) brightness temperature difference versus visible brightness count corrected for solar zenith angle were employed in September 2003, followed by inclusion of cloud top heights from the GOES Sounder Cloud Top Product in February 2004. The latter combination, referred to as ICECAP (Icing Enhanced Cloud-top Altitude Product), was made available on the Web in February 2004. Finally, a correction to reduce the over-detection of icing caused by thin cirrus was employed in September 2004, based on a technique that uses Bands 4-6 (10.7-13.3 micrometers). Probability of detection (determined from the NOAA Forecast Systems Laboratory's Real-Time Verification System) is now consistently in the 55-70 percent range for the Continental U.S.

FOG AND LOW CLOUDS

GOES-12 visible and IR data for a case of sea fog over the northeast U.S. in June 2003, was analyzed to determine if the fog could be discriminated objectively from other cloud types. The results were provided to the NWS Meteorological Development Laboratory, which is developing objective sea fog forecasting techniques using surface, model, and satellite data.

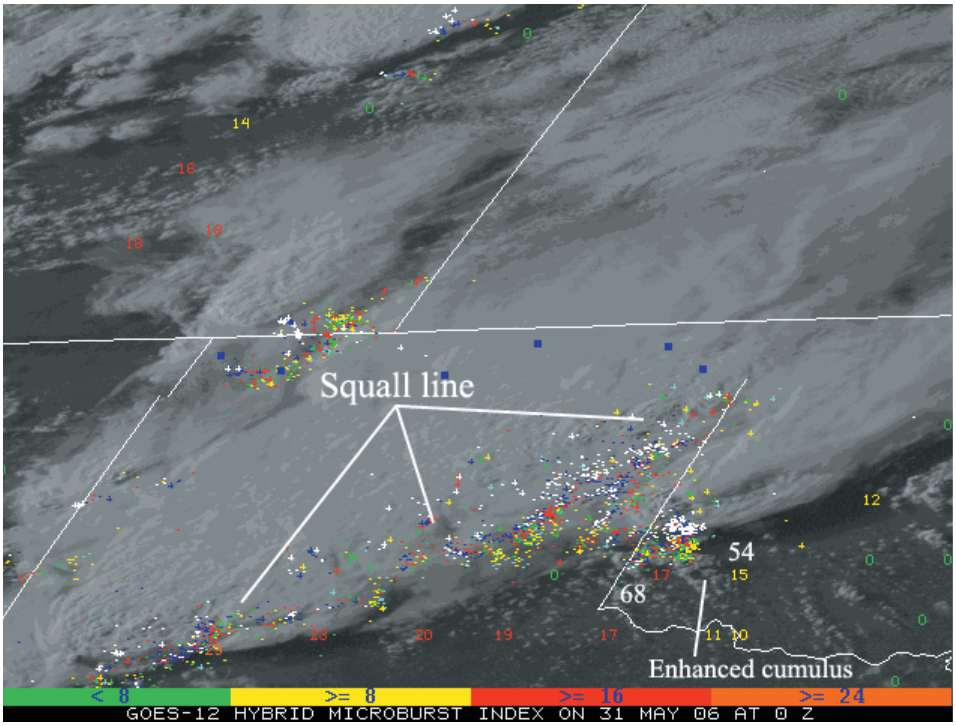


Figure 3-DOC-8. An Example of the GOES HMI Product.

GEOSTATIONARY SEA SURFACE TEMPERATURES

GOES-12 and GOES-11 are capable of producing sea surface temperatures (SST) over most of the Western Hemisphere nearly continuously. The accuracy and spatial resolution achieved with the GOES measurements are close to that achieved from the polar orbiting platforms, and GOES has a unique advantage of high temporal sampling frequency. Unfortunately, the trade-off of replacing the 12.0 µm channel with a 13.3 µm channel notably impacts the SST retrievals by eliminating the capability for daytime split-window retrievals, increasing the rms error by about 0.5 C. For the SST determination, the frequent sampling by GOES makes a more complete map of SST possible after clouds have moved on. Additionally, a change in scene temperature over a short period of time may indicate the presence of clouds, thereby enhancing cloud detection.

The abundance of GOES observations helps to maintain a balance between high-quality, cloud-free observations and good geographical coverage of SST estimates. GOES is enabling quantification of the diurnal variation of a radiometrically determined SST over large areas and long time periods. This quantification may have important implications in both numerical weather prediction and climate monitoring. NESDIS has been producing the GOES SST hourly in an experimental configuration since December 1998, from both GOES East and GOES West. A global SST product is produced every three hours; regional SST products are generated every hour. These products were recently implemented operationally and can be accessed as digital files from the GOES computer servers within OSDPD.

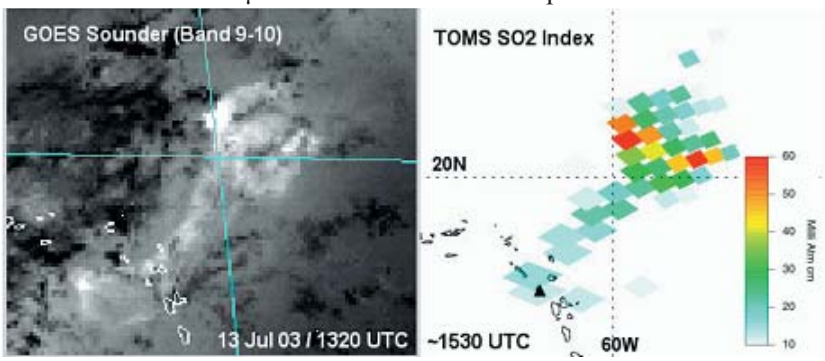


Figure 3-DOC-9. Comparison of GOES Sounder Band 9 minus Band 10 (left) versus the SO2 Index from the Total Ozone Mapping Spectrometer (TOMS) instrument (right) on July 13, 2003 are shown for the indicated times. The SO2 cloud was emitted from an eruption of Soufriere Hills Volcano, Montserrat (located shown in bottom of right hand image) that began around 0600 UTC, July 13, 2003.

VOLCANIC ASH

A new technique has been developed to mitigate the loss of the 12 µm IR band on GOES-12 to help track hazardous volcanic ash clouds. The technique uses IR channels centered at 10.7, 13.3, and 3.9 µm. Several recent eruptions of Soufriere Hill's volcano on Montserrat Island in the eastern Caribbean have shown that this new product is helpful in monitoring ash cloud emissions even at night. GOES-12 ash product can be viewed for several volcanically active regions at http://www.ssd.noaa.gov/VAAC/. The analysis of Moderate Resolution Imaging Spectroradiometer (MODIS) data from the NASA Terra and Aqua spacecraft has also yielded valuable information about optimum detection of volcanic ash using several spectral bands. A three-channel combination product based on the 8.6, 11, and 12 µm bands has been developed that provides effective discrimination of ash or sulfur dioxide gas with minimal false alarms. This algorithm could be applied to future products from NPOESS and GOES-R, which will have similar spectral bands. Volcanic

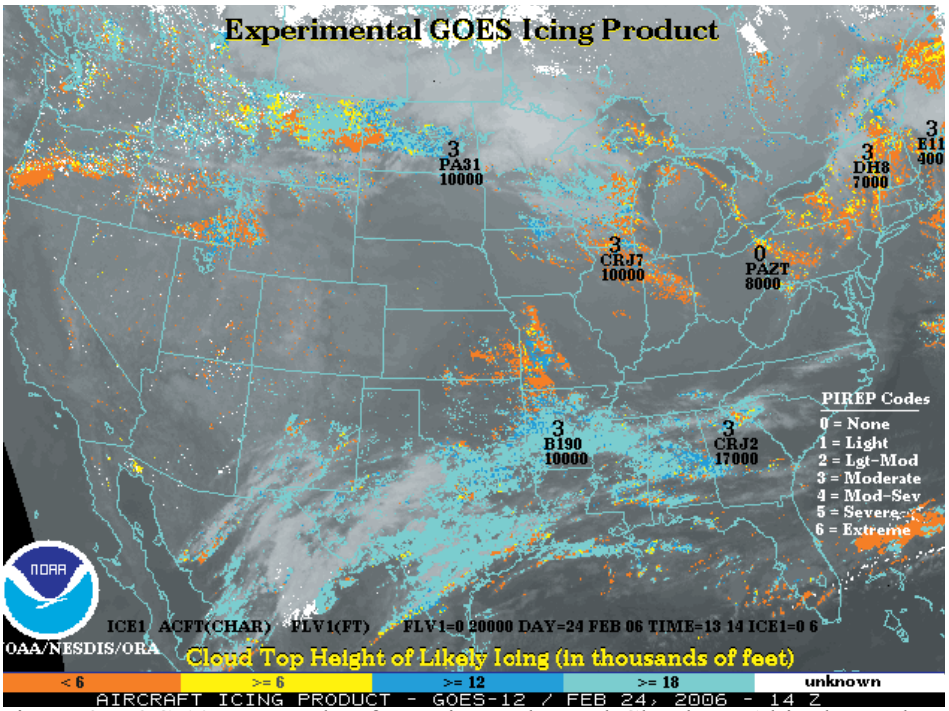


Figure 3-DOC-10. Example of an Icing Enhanced Cloud-top Altitude Product (ICECAP) image is shown, valid at 1700 UTC, on February 17, 2004. Areas of potential icing are color-coded in intervals of 6,000 ft to show maximum cloud top altitude. Pilot reports of icing are superimposed showing: numerical icing intensity (0 to 5), aircraft type, and altitude in feet. Severe icing (code 5) at 8,000 ft was reported in eastern Tennessee within two hours of the GOES product. Some icing (such as that shown in northwest U. S.) is obscured by high cloud layers and cannot be detected.

Ash Advisories (VAA) with associated Volcanic Ash Graphics (VAG) and ash forecasts are provided by NESDIS to the aviation community. The region of coverage is the continental U.S., Central America, northern South America to 10 degrees S, the Caribbean region, the Pacific Ocean south of Alaska and the Aleutians Islands, and, to the east of Japan, the Marianas Islands. The Volcanic Ash Advisory Center (VAAC) is located in Camp Spring, Maryland. GOES infrared and visible images, aerosol and sulfur dioxide products from NASA's Total Ozone Mapping Spectrometer (when applicable), and operational volcanic ash products for the Washington VAAC area of responsibility can be found at http://www.ssd.noaa.gov/VAAC/washington.html.

In addition to current operational products for volcanic ash, research into new and improved ways to detect volcanic ash are ongoing. Relevant bands from experimental multi-spectral and hyper-spectral satellite instruments, especially those spectral bands scheduled to be on future operational satellites, are being probed in the development of new products for the detection of volcanic ash. That is in addition to the improved spatial, temporal, and radiometric resolution offered by next-generation satellites.

FIRE MONITORING

Geostationary and polar-orbiting meteorological and environmental research satellites have been used to detect and monitor large active wildfires for over 20 years. Early work using the NOAA-6 AVHRR demonstrated how the different brightness temperature responses between the shortwave infrared (SWIR at 3.74 µm) and the long wave infrared window (LWIR at 10.8 µm) bands can be used to locate fires and estimate fire characteristics (e.g., instantaneous sub-pixel fire size and temperature). Since then algorithms have been developed at NOAA, NASA, and the Cooperative Institutes (UW-Madison - CIMSS, Colorado State University - CIRA) to utilize NOAA operational satellites (GOES Imager, POES AVHRR), research satellites (EOS MODIS, TRMM, ATSR, etc.), and defense satellites (DMSP OLS) to identify and monitor fires in near, real-time. In the mid-latitudes polar orbiting instruments (EOS-MODIS, POES AVHRR) provide several observations of a given region each day with more frequent observations near the poles. In routine mode the GOES Imager allows for fire monitoring every 15 minutes over CONUS and half-hourly throughout the rest of North, Central, and South America. Plans are underway to provide GOES Rapid Scan fire data every few minutes when available.

Since 2002, the NOAA NESDIS Satellite Service Division has provided fire products on-line via the Hazard Mapping System (HMS) (http://www.firedetect.noaa.gov). The HMS is an operational interactive processing system that integrates fire products from seven different sensors on NOAA (POES AVHRR, GOES Imager, DMSP OLS) and NASA (EOS MODIS) satellites to produce fire and smoke product analyses for the U.S. and parts of Canada and Mexico. Automated algorithms including the MODIS Fire and Thermal Anomalies team algorithm, the GOES Wildfire Automated Biomass Burning Algorithm (WF_ABBA), the AVHRR Fire Identification Mapping and Monitoring Algorithm (FIMMA), and the DMSP OLS algorithm are used to generate the fire products while smoke is delineated by an image analyst. Analyses are quality controlled by an analyst who inspects all available imagery and

automated fire detects, deleting suspected false detects and adding fires that the automated routines miss. Graphical, text, and GIS compatible analyses are posted to the HMS web site. All products are archived at NOAA's National Geophysical Data Center (http://map.ngdc.noaa.gov/website/firedetects).

Over the past 10 years, the use of these satellite derived fire products has grown appreciably with applications in hazards monitoring, fire weather forecasting, climate change, emissions monitoring, aerosol and trace gas transport modeling, air quality, and land-use and land-cover change detection. The user community includes government agencies (such as NOAA, NASA, EPA, and USFS), resource and emergency managers, fire managers, international policy and decision makers, educational institutions, and the general public. At NOAA's National Severe Storms Laboratory (NSSL) Storm Prediction Center (SPC) GOES WF_ABBA fire products provided by UW-Madison CIMSS are used in fire weather forecasting. The SPC Fire Weather Analysis Page (http://www.spc.noaa.gov/exper/firecom) integrates the GOES WF_ABBA fire product with other meteorological data and fire weather and danger indices (Haines, SPC LASI, Fosberg Index, etc.) to provide an overview of existing fires and fire danger in the continental U.S.. Since 2000, the Naval Research Laboratory in Monterey (NRL - Monterey) has been assimilating the GOES WF_ABBA and MODIS fire products (as of 2003) into the NRL Aerosol Analysis and Prediction System (NAAPS) in near, real-time to both monitor and predict aerosol loading and subsequent transport around the world (http://www.nrlmry.navy.mil/flambe/index.html). In Brazil, INPE/CPTEC has been assimilating the data into their air quality/transport models in real-time for several years (http://tucupi.cptec.inpe.br/meio_ambiente/).

Current research includes the development and implementation of a near,, real-time operational global geostationary fire monitoring network to monitor fires as they occur and capture the diurnal signature around the globe. Initially the GOES WF_ABBA is being adapted to Meteosat-8 and MTSAT-1R. Plans are underway to eventually adapt the WF_ABBA to FY-2C SVISSR (China), INSAT-3D (India), and the GOMS Electro N2 (Russia). This suite of geostationary sensors will enable nearly global geostationary fire monitoring with significant regions of overlap in Asia. Future activities include better utilization of current systems and long-term plans that ensure the capability to derive similar or improved and enhanced fire products with next generation operational polar-orbiting (NPOESS, Metop) and geostationary (GOES-R, MTG) series.

AIR QUALITY PRODUCTS

Since their inception, NOAA operational satellites have been monitoring the Earth's environment (e.g., Antarctic ozone hole) and climate (e.g., stratospheric ozone trends). While the need for this information continues to be met, NOAA's mission has expanded to include monitoring and forecasting air quality. Continuing detrimental impacts of air pollution (ozone and PM2.5) on human health and the economy led the U.S. Congress to issue various mandates to the Environmental Protection Agency (EPA) and NOAA to combat and mitigate pollution (e.g., H.R.4. Energy Policy Act of 2002, Senate Amendment). To meet the mandates, NOAA and EPA signed a Memorandum of Understanding (MOU) and a Memorandum of Agreement (MOA) in 2003.

The MOU calls for developing and deploying an operational air quality forecast system capable of issuing nationwide hourly air quality forecasts of ozone by 2007, and PM2.5 (particles smaller than 2.5 µm in diameter) by 2014. The NOAA/NWS has begun issuing operational ozone forecasts and experimental PM2.5 forecasts in the northeast in 2004, using the Eta-CMAQ (Community Multiscale Air Quality Modeling) system.

The MOA calls for cooperation in air quality research between NOAA and EPA by developing methods for using observations to improve predictions of air quality. NESDIS has begun supporting the MOA by providing near,real-time data such as ozone and aerosols to the NWS for operational air quality and UV Index forecasting applications.

The assimilation of satellite measurements of physical parameters (e.g., observations of temperature and moisture) into numerical weather prediction models to improve weather forecasts has grown tremendously in the last two decades and has proven to have a positive impact on weather forecasts. Satellite chemical data assimilation, on the other hand, is still in its infancy, especially since both operational air quality forecast systems and satellite sensor technology capable of measuring boundary layer pollutants are still evolving. While the ability to measure various tropospheric pollutants at the desired spatial resolution, temporal resolution, and accuracy remains a challenge, the need to exploit the measurements from current and soon-to-be launched sensors to monitor and improve air quality forecasting is imminent. NOAA/NESDIS is actively involved in using research satellite data (e.g., EOS Aura OMI and Aqua/Terra MODIS) to demonstrate the capabilities of enhanced sensors and prepare NOAA and its users for IJPS, NPOESS, and GOES-R datasets. EUMETSAT is launching the GOME-2 and IASI instruments, which are capable of measuring trace gases and aerosols, into a polar orbit with 9:30

A.M. equator crossing time. Products from these instruments are available to NOAA. NPOESS will have OMPS and CrIS sensors with similar capabilities and will fly with a 1:30 P.M. equator crossing time. The IJPS (~2006 and beyond) and NPP/NPOESS (~2009 and beyond) systems are expected to provide continuous monitoring of trace gases and aerosols into the 2020s.

Together, these sensors will have a capability to measure tropospheric column amounts of trace gases (ozone, nitrogen dioxide, formaldehyde, sulfur dioxide, carbon monoxide, etc.) in addition to aerosol products at spatial resolutions similar to forecast models. Routine observations on such high spatial and temporal scales cannot be matched by any ground observations and are critical for monitoring and assimilation applications. NOAA/NESDIS is currently developing GOME-2 ozone products for near,real-time dissemination to users (Table 3.2).

The ABI and the HES instruments on the next generation Geostationary Environmental Operational Satellite (GOES), Series R, will provide unprecedented information on air quality. Plans are currently underway to develop various air quality products for the Americas at temporal resolution ranging from 5 to 60 minutes for the imager and sounder respectively. These products are expected to become operational after the launch of GOES-R in 2013 (Table 3.3).

CURRENT PRODUCTS AND APPLICATIONS

Aerosol Optical Depth (AOD). Satellite measured AOD has been shown to be a good proxy for pollution monitoring especially when long-range transport is involved. NESDIS/STAR has been providing to its users GOES AOD product in near, real-time since 2003. This product is available at 30-minute intervals and 4 km × 4 km spatial resolution during the sunlit portion of the day. EPA and NWS have been using the product for monitoring and forecasting applications.

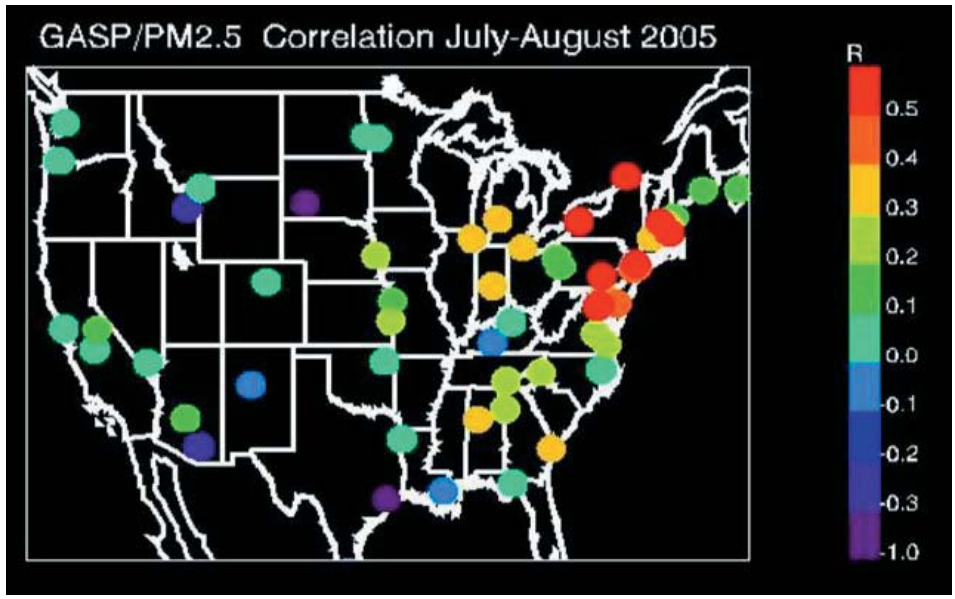


Figure 3-DOC-11. Shows mean bias between satellite measured aerosol optical depth and NWS experimental forecast during July 15 - August 15, 2004.

Emissions. Emissions from both natural and anthropogenic sources contribute to poor air quality. Biomass burning (prescribed and wild fires) release huge amounts of smoke (primary particulates dominated by black carbon) and trace gases into the atmosphere. Power plants, oil refineries, and other industrial sources release NO2 (nitrogen dioxide), H2CO (formaldehyde), SO2 (sulfur dioxide), and other organic compounds leading to poor air quality as well. The EPA compiles a National Emissions Inventory (NEI) every year for a number of critical environmental management and policy activities such as tracking the Clean Air Act and Clean Air Interstate Rule. Emissions data are used to determine trends over time as well as to initialize air quality forecast models. One of the primary sources of uncertainty in air

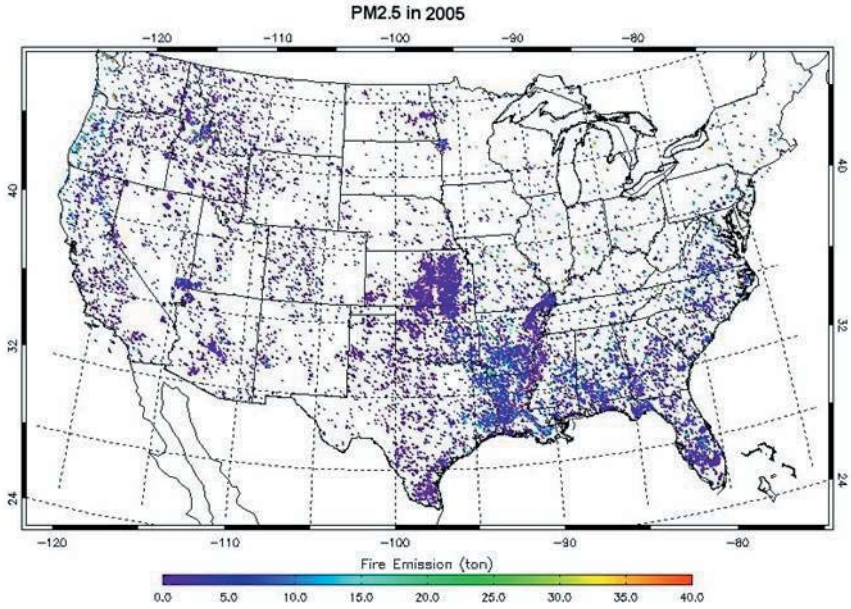


Figure 3-DOC-12. Annual PM2.5 emissions for 2003 from biomass burning events as observed by GOES-12 Imager

TABLE 3.2 TRACE GAS AND AEROSOL PRODUCTS FROM OPERATIONAL POLAR-ORBITING SATELLITES

Pollutant	Location	Satellite (Sensor)	User/Application
NO_2	Troposphere	IJPS (GOME-2)	NWS – Assimilation NWS – Forecast model evaluation EPA – Assessment work (emissions) Model evaluation NOAA – Model evaluation
SO_2	Troposphere Stratosphere (volcanic)	IJPS (GOME-2) NPP/NPOESS (OMPS) IJPS (IASI) NPP/NPOESS (CrIS)	NWS – Forecast model evaluation EPA – Model evaluation NOAA – Model evaluation
H_2CO	Troposphere	IJPS (GOME-2) NPP/NPOESS (OMPS)	NWS – Forecast model evaluation EPA – Assessment work (emissions) Model evaluation NOAA - Model evaluation
CHOCHO	Troposphere	IJPS (GOME-2)	EPA – Assessment work (emissions)
O_3	Column	IJPS (GOME-2) IJPS (IASI) NPP/NPOESS (OMPS) NPP/NPOESS (CrIS)	NWS – Assimilation
O_3	Profile (stratosphere)	IJPS (GOME-2) NPP/NPOESS (OMPS)	NWS – Assimilation
CO	Troposphere	IJPS (IASI) NPP/NPOESS (CrIS)	EPA – Assessment work (emissions) NWS – Forecast model evaluation
CH_4	Column	IJPS (IASI) NPP/NPOESS (CrIS)	EPA – Assessment work (emissions)
CO_2	Column	IJPS (IASI) NPP/NPOESS (CrIS)	NOAA – Climate monitoring
BrO	Stratosphere	IJPS (GOME-2)	NOAA – Climate monitoring NASA – Climate monitoring
OclO	Stratosphere	IJPS (GOME-2)	NOAA– Climate monitoring NASA – Climate monitoring
Aerosols	Troposphere	IJPS (GOME-2) IJPS (IASI) NPOESS (OMPS) NPOESS (CrIS) NPOESS (VIIRS) NPOESS (APS)	NWS – Assimilation NWS – Forecast model evaluation EPA – PM2.5 monitoring

TABLE 3.3 GOES-R BANDS AND PRODUCTS

Sensor	Bands	Product	Applications
ABI	0.47µm, 0.86µm, 2.1µm	Aerosol optical depth, type (dust vs. non dust), particle size (effective radius), and fraction of fine mode vs. coarse mode	EPA – PM2.5 monitoring NWS – PM2.5 forecasting NIEHS – Health impacts CDC – Health impacts
ABI	9.6µm	Total column ozone	FAA – Clear-air turbulence NWS – Ozone forecasting
ABI	3.9µm, 11µm	Fire location, size, intensity and carbon consumption Aerosol and trace gas emissions	EPA – Assessments NWS – Forecasting
ABI	11µm, 12µm	Dust detection	EPA – Monitoring
HES	800 – 1000 cm^{-1}	Dust loading and height Volcanic ash detection, amount and height Smoke plume height	VAAC – Advisories EPA – Monitoring NWS – Forecasting
HES	1650 – 2250 cm^{-1}	Carbon monoxide Methane	EPA – Assessments NWS – Forecasting NOAA – Climate
HES	950 – 1050 cm^{-1}	Ozone profile	NWS – Forecasting
HES	600 – 800 cm^{-1}	Ash cloud height Smoke plume height	VAAC – Advisories NWS - Forecasting
HES	1100 – 1200 cm^{-1}	Sulfur dioxide	VAAC – Advisories

quality forecasts comes from the uncertainties in these emissions. NESDIS/STAR developed algorithms to derive emissions of PM2.5 and trace gases from biomass burning. These products will be provided to NWS in near, real-time for assimilation into air quality forecasting models.

3D Air Quality Mapping System. Satellite data have been very useful in diagnosing long range transport, primarily because this occurs in free troposphere and is more easily detected by satellites. NOAA is interested in the issue of entrainment of pollutants transported from long distances into the boundary layer and the impact on local air quality. NASA launched CALIPSO in April 2006, which has a Lidar on board that can detect tropospheric vertical profiles of aerosol backscatter ratio. These measurements combined with column aerosol optical depth retrievals will become very valuable in providing a three-dimensional look at pollution plumes. Additionally, integrating data from multiple sensors will optimize the information on aerosol type, location in space (horizontal and vertical scale), and time (GOES aerosol observations have a refresh rate of 30 minutes). Satellite Meteorology and Climatology Division (SMCD) scientists are co-investigators of the NASA funded 3D Air Quality System project which will investigate combining information from various sensors to build 3D air quality measures that can be applied to studying linkages between human health and air quality.

Numerical Modeling. The NWS has already begun issuing ozone forecasts for the northeast and conducting experimental PM2.5 forecasts. They currently use the Eta-CMAQ modeling system and will soon migrate to the WRF (Weather and Research Forecast) model with integrated meteorology and chemistry. Primary sources of uncertainties in model forecasts are from uncertainties in initial/boundary conditions and emissions. Satellite data, when assimilated into the models, have the potential to improve forecasts by providing initial/boundary conditions and constraining emissions. In situ data collected during field campaigns will be very useful in verifying the forecasts and diagnosing various sources of uncertainties in both models and satellite data. Chemical data assimilation is in its infancy; only ozone has been successfully assimilated and demonstrated to have an impact on surface ozone. Methodologies to assimilate other trace gases (e.g., NO2) and aerosols in an operational forecast mode are yet to be developed.

Other Applications. Measurements of trace gases and aerosols from a geostationary platform bring about unique applications due to their high temporal sampling. For example, a total ozone product available at an hourly refresh rate from GOES-R will be a very useful product for the Federal Aviation Administration (FAA) to monitor clear air turbulence. Similarly, an ability to monitor signatures of dust loading, type, and vertical location provides unprecedented information for air quality and climate applications. The ability to distinguish between different aerosol types is extremely important for air quality monitoring and forecasting applications. GOES-R trace gas retrievals such as O3, CO, CH4, CO2 are expected to serve the needs of air quality, climate, and health community from a monitoring and modeling perspective.

While the currently used ozone data in the models and monitoring come from polar-orbiting satellite sensors, the capability of geostationary satellites to provide synoptic ozone measurements on similar time and spatial scales as existing operational air quality models and surface networks is essential for proper characterization of ozone in the troposphere. Specifically there is a need for this data from geostationary satellites because hourly measurements:

- Provide more cloud-free data which are necessary for providing constraints on tropospheric ozone and are essential for the EPA to understand relationship between tropospheric column ozone and observed surface ozone from ground monitors under varying meteorological conditions.
- Reduce aliasing of synoptic scale transport patterns relative to polar-orbiting sensors, which is essential for capturing upper tropospheric ozone variations associated with folding events.
- Are essential for the EPA to monitor diurnal changes.
- Are needed for surface energy flux algorithms, photolysis rate calculations in air quality models, and other similar applications (specifically total ozone measurements).

Atmospheric Winds. Atmospheric motion vectors (AMVs) derived from a sequence of satellite images are an important source of global wind information, particularly over the world's oceans and more remote continental areas where conventional weather observations are lacking in time and space. These data are routinely used by the major Numerical Weather Prediction (NWP) centers in the world and assimilated into regional and global NWP prediction models. These data are also made available to NWS forecasters responsible for providing the public with day-to-day weather forecasts. In addition, these products are distributed over the Global Telecommunication System (GTS) and the NWS Advanced Weather Interactive Processing System (AWIPS).

AMVs are typically derived from the GOES imagery providing coverage from approximately 60 degrees S to 60 degrees N. The current operational GOES wind products include infrared (IR) cloud-drift winds, water vapor (WV) motion winds, and visible (VIS) cloud-drift winds. Figure 3-DOC-12

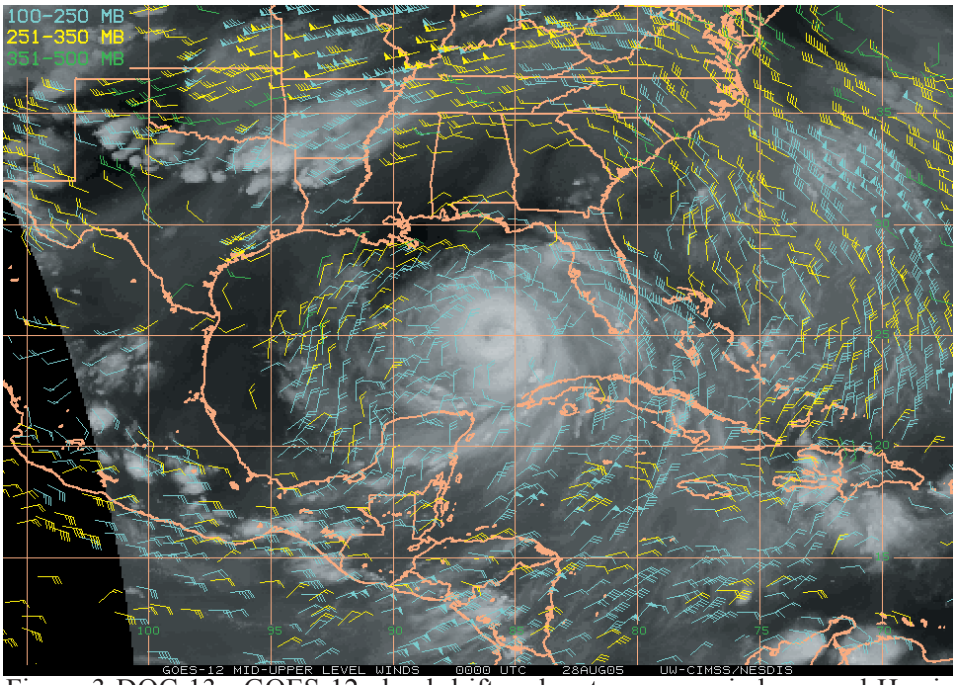


Figure 3-DOC-13. GOES-12 cloud-drift and water vapor winds around Hurricane Ivan at 18Z on September 13, 2004 overlaid on composite, true color image generated from multiple GOES imager channels.

shows an example of GOES-12 cloud-drift and water vapor winds around Hurricane Ivan at 18Z on September 13, 2004.

The capability to derive AMVs from measurements made by the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard the polar-orbiting Terra and Aqua satellites was first developed at the Cooperative Institute for Meteorological Satellite Studies (CIMSS) and is based upon established methodologies and algorithms used to derive wind observations from the GOES series of satellites. MODIS cloud-drift and water vapor wind observations from Terra and Aqua provide unprecedented coverage in the polar regions of the globe, areas where wind observations are sorely lacking. Figure 3-DOC-13 shows an example of the MODIS water vapor motion wind products in the Northern Hemisphere polar region.

In 2004, the MODIS winds capability was integrated within the existing operational NESDIS winds processing system. Significant modifications made to the algorithms included targeting from the middle image in the image triplet and using the National Centers for Environmental Prediction's (NCEP's) global forecast model grids as the first guess in the MODIS winds processing scheme. Targeting from the middle image in the image sequence had a significant impact on the pattern recognition/feature tracking process, which significantly improved the quality of the MODIS wind products. Experimental, near, real-time production of MODIS winds from Terra and Aqua was established at NESDIS and product datasets made available to the NWP user community. Near, real-time experimental MODIS wind products from Aqua and Terra were generated, distributed, and archived in support of two MODIS Winds Special Acquisition Periods (MOWSAPs) aimed at providing MODIS wind products to numerous NWP centers for subsequent model impact studies. MOWSAP-I covered November 5, 2003, to December 31, 2003, and MOWSAP-II covered July 5, 2004, to August 23, 2004.

NWP centers involved in assessing the MODIS winds during MOWSAP included: NWS/NCEP, European Center for Medium Range Weather Fore-

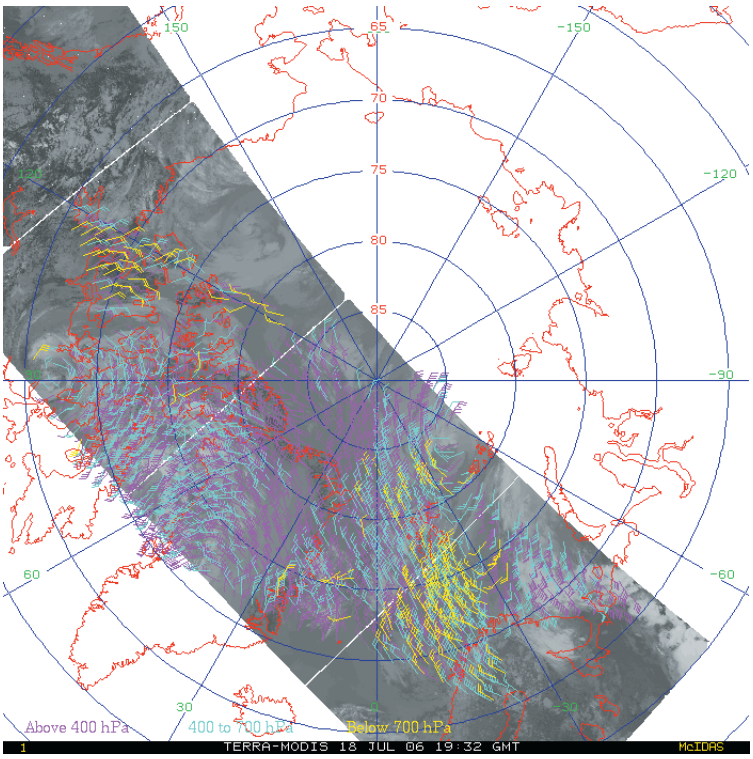


Figure 3-DOC-14. MODIS water vapor motion winds over the Northern Hemisphere polar region.

casting (ECMWF), United Kingdom Meteorological (UKMET) Office, Canadien Meteorological Center (CMC), the German Weather Service, and NASA's Global Modeling Assimilation Office (GMAO). Forecast impact results from all NWP centers involved in the MOWSAP test periods showed that the MODIS wind products have a significant positive impact on forecast accuracy in the Arctic and Antarctic, as well as in the extra-tropics of both the Northern and Southern Hemispheres. Given the positive forecast impact results, the MODIS winds capability was transitioned to OSDPD/Satellite Services Division (SSD) where they routinely provide MODIS AMVs to the NESDIS user community.

Areas of active AMV research include: upgrades to the MODIS AMV processing, improved quality control of AMVs, investigating optical flow approaches to the problem of feature tracking, and the derivation of AMVs from rapid scan GOES imagery.

In the U.S., GOES has been used in operational forecasting for quite some time. Forecasters recognize the additional detail that can be captured from more frequent imaging in events associated with rapidly changing cloud structures. The value of more frequent imaging is demonstrated by the inclusion of a 15-minute update cycle over the Continental United States (CONUS) sector in the current GOES schedule and by the multitude of special NWS operational requests for more frequent sampling at 7.5 minute intervals (Rapid-Scan Operations, RISOP). On occasion, special periods of Super-Rapid-Scan Operations (SRSO) have been requested by the research community. The SRSO allow limited-area coverage of one-minute interval sampling over meteorological events of interest.

Recently, special GOES RISOP periods have been collected during several field programs and research initiatives designed to maximize observational abilities in regions of high-impact weather events. Some examples include the NASA Tropical Cloud Systems Program (TCSP), the Atlantic Thorpex Regional Campaign (ATReC), and the TROpical Predictability EXperiment (TROPEX). In ATReC and TCSP, the datasets were used in real-time in mission planning and/or directing aircraft to targets of opportunity. In TROPEX, the datasets will be used in targeted observing strategy experiments run by modelers at the Naval Research Laboratory. In all three cases, the enhanced datasets are expected to be employed in case study analyses and numerical model impact studies.

Integrated Cal/Val Enterprise System. The users of numerical weather predictions require accurate calibration of satellite measurements. For satellite measurements having anomalies in radiances and/or large systematic biases, the data will be rejected during the data assimilation stage. It is also very difficult to use the satellite observations that are not quantified for their measurement precision. For climate studies, satellite instruments must be capable of measuring Earth system variables at high accuracy and stability over decadal (and ultimately, centennial) time scales. During a calibration workshop organized by NIST, NOAA, NPOESS-IPO, and NASA in November 2002, accuracy and long-term stability objectives for satellite measurement were established. The final report of the workshop defines the required absolute accuracies and long-term stabilities of global climate data sets, and it translates the data set accuracies and stabilities into the required satellite instrument accuracies and stabilities (e.g., for troposphere atmospheric temperatures, the measurement accuracy is 0.5 K and stability is 0.04 K/decade; for surface albedo measurement, the accuracy is 0.01 and stability is 0.002 K/decade). Those requirements pose tremendous challenges to the post launch calibration of satellite sensors.

NESDIS/STAR has an excellent track-record in supporting the operational calibration of radiometers on polar-orbiting environmental satellites, transferring research results to operations and performing advanced research in satellite instrument calibration. In addition to our heritage in on-board and vicarious calibration, in recent years we have developed many additional components such as inter-satellite calibration, on-orbit and prelaunch instrument characterization, and the incorporation of radiative transfer model calculations.

STAR also plays an important role in re-calibrating historical data to support climate studies, through the scientific data stewardship program. In recent years, STAR has developed comprehensive calibration/validation capabilities which are being incorporated into the Integrated Calibration and Validation enterprise System (ICVS). The vital components of the ICVS include prelaunch and on-orbit quantification of satellite instrument noise and on-line performance monitoring; linear and non-linear thermal calibration; on-board ultra-violet (UV), vicarious visible and near-infrared calibration; independent verification of radiances through inter- and intra-satellite calibration; and radiative transfer calculations to isolate biases and anomalous contributors to the biases. Today, we can quantify the on-orbit instrument noise and biases with little ambiguity, significantly reducing the uncertainties for the data users in direct radiance assimilation in numerical weather prediction, physical retrievals, and climate monitoring and reanalysis.

With the ICVS framework, STAR is now in an excellent position for leading and coordinating the WMO Global Space-based Intercalibration Calibration System (GSICS). The GSICS is to integrate observations and products

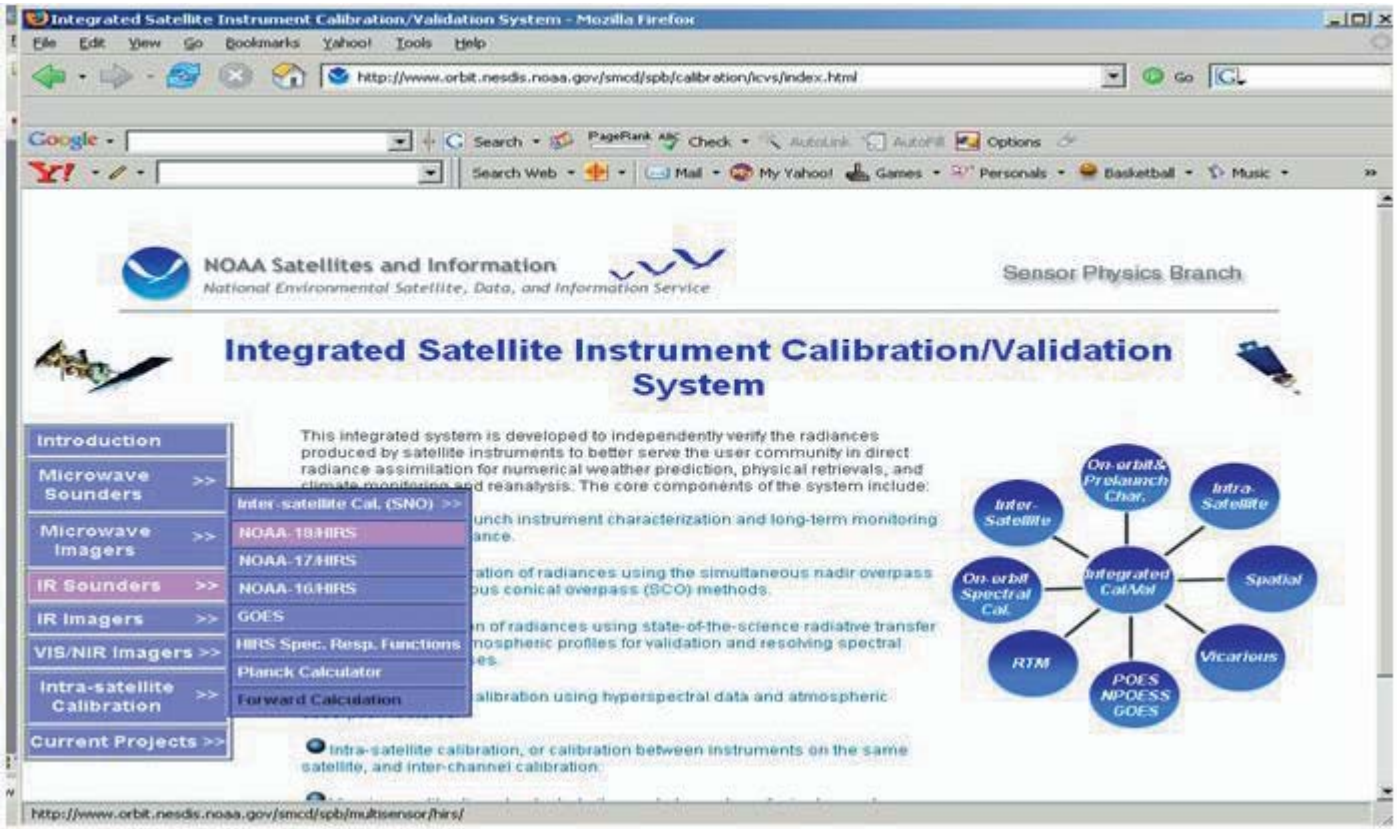


Figure 3-DOC-15. NOAA's Integrated Satellite Instrument Calibration/Validation System.

from different satellite systems through intercalibration. The intercalibration can quantitatively relate the radiances from different sensors viewing the same target and allow consistent measurements to be taken over the globe by all elements of the space-based observing system. Without inter-calibration of the space-based component of the World Weather Watch (WWW) Global Observing System and of GEOSS, the full benefit of the observations will not be realized for the environmental data stewardship.

During the 2005 hurricane season, the ICVS was first applied for NOAA-18 on-orbit verification and led to an early delivery (45 days after NOAA-18 launch) of high quality satellite observations for uses in NOAA computerized models that significantly improve the accuracy and extend the range of weather prediction for severe storms such as hurricane track, wind damage, and surface flooding. This results in an overall savings equivalent to 2.5 percent of the total cost of the satellite with a lifespan of 5 years (~200 million dollars) or ~5 million dollars. With the ICVS, STAR scientists are able to provide an accurate analysis of the root cause of the NOAA-18 HIRS/4 anomaly and provide mitigation strategies for containing the noise and reducing the risk for future

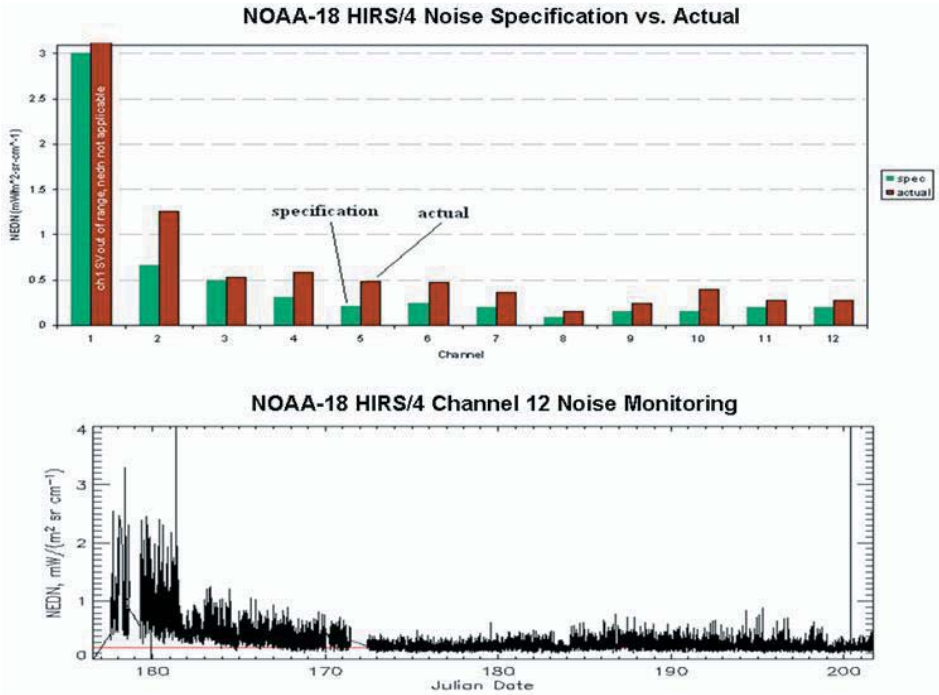


Figure 3-DOC-16. ICVS was first applied for NOAA-18 on-orbit verification.

launches (see Figures 11 and 12).

The ICVS is also providing a root-cause analysis and diagnostics for DMSP Special Sensor Microwave Imager and Sounder (SSMIS) radiance anomalies. The SSMIS is the first conically-scanning microwave instrument that measures the Earth's radiation from 19 to 183 GHz and presumably provides improved atmospheric temperature and water vapor sounding under all weather conditions. It is a key sensor for NPOESS risk reduction studies. Unfortunately, the main reflector from the SSMIS antenna subsystem emits some radiation and contaminates the Earth scene signals. In addition, the warm calibration target is intruded by direct solar radiation and other stray lights, producing anomalous calibration counts in several latitudinal zones. These contamination sources cause anomalies in SSMIS radiances in Temperature Data Records (TDR) and Sensor Data Records (SDR), which change with latitude and season. As part of the ICVS, the SSMIS anomaly distributions (locations and magnitudes) are detected and corrected during the calibration process. Therefore, the SSMIS data after the NOAA recalibration and processing is of improved quality for operational applications in weather and climate models (see Figure 3-DOC-17).

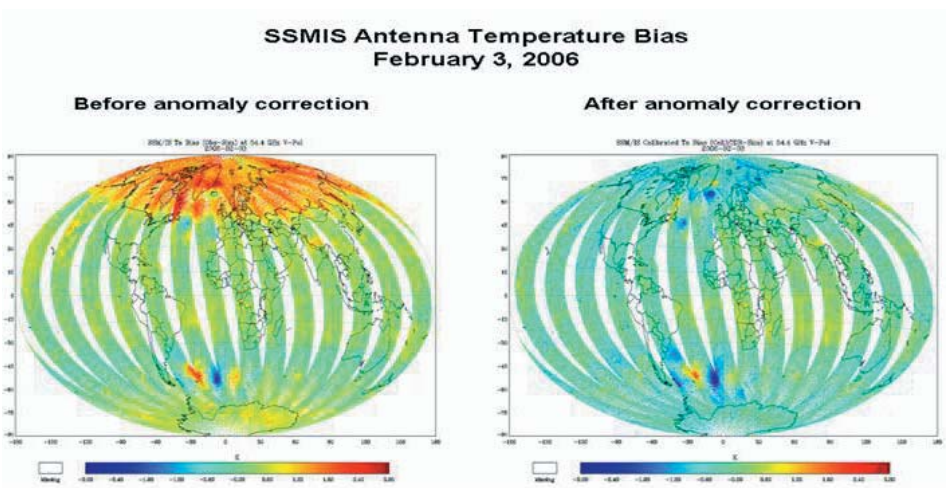


Figure 3-DOC-17. SSMIS anomaly distributions (locations and magnitudes) are detected and corrected during the calibration process.

NPP/NPOESS Sensor Calibration, Product Developments, Enhancement, and Validation. STAR scientists continue to play an important role in the evaluation of NPOESS contractor sensor design and retrieval methods. This group provides the end-to-end support to NPOESS program from instrument calibration to product validation and applications. STAR scientists have also been participating in NPOESS operational algorithm teams (OAT) and all phases of the NPOESS sensor calibration process to assure that radiometric performance of NPP/NPOESS instruments will meet the scientific needs of NOAA and other agencies.

STAR scientists have also been providing significant technical support to the prelaunch calibration of major NPOESS instruments in the last few years. As early as 2001, STAR scientists contributed to the technical design of the several major NPOESS instruments and supported the investigation of prelaunch calibration issues using comparisons with current POES instruments and evaluating how they affect the calibration traceability between POES and NPOESS. Currently, STAR is providing technical examination of the calibration accuracy, NE T, and nonlinearity for several instruments such as ATMS.

In the NPOESS post-launch calibration, STAR will focus on the characterization of on-orbit instrument noise and biases of all NPOESS instruments using the STAR integrated cal/val enterprise system and develop an on-line instrument performance trending system that monitors a selected number of key parameters.

It is critical to the NPOESS program and to the scientific community at large that the contractor scientific algorithms are assessed independently during the pre-launch phase so that potential corrective measures are taken early, avoiding sub-optimal results later in the process and/or delays in delivering the real-time data to weather centers and other customers after launch has occurred. STAR scientists have proposed a vigorous assessment of radiometric and geophysical performances of NPP/NPOESS instruments, in both pre-launch and post-launch stages. Further assessments will be made to check the robustness and the timing requirements for an operational use.

The contractor algorithms are being extensively compared in simulation and with real data, with operational products developed by STAR from EOS, POES and DMSP platforms. STAR is a center with various proxy data sets and testbeds through simulations and real measurements for NPOESS instruments. NPOESS contractor algorithms are now being run at the STAR systems and assessed with the proxy data. Since the STAR team have dual experience with both the contractor algorithms and in the operational algorithms running at NOAA, there have been rapid advances in the assessment of the contractor's algorithms performances.

NPOESS "test bed" data sets. STAR scientists continue to play an important role in the evaluation of proposed contractor sensor design and retrieval

methods during the ongoing selection process for NPOESS. STAR scientists have created a variety of test bed data sets that are being used in the algorithm evaluation process. This is accomplished through participation in operational algorithm teams with the long-term goals of assuring capability to meet the requirements of all Environmental Data Records. Ozone evaluation, calibration, and validation activities took place for the new Solar Backscatter Ultraviolet Instrument (SBUV/2) with the launch and successful checkout of NOAA-17. A new ozone profile retrieval algorithm has been developed by NASA and is now incorporated into SBUV/2 processing systems. Monitoring of global ozone will continue with the SBUV/2 instruments on NOAA-14, NOAA-16 NOAA-17, and NOAA-18 and with the TOVS instruments on NOAA-14, NOAA-15, NOAA-16, NOAA-17 and NOAA-18. Experimental high temporal ozone products are also being produced from the GOES-12 sounder channels. Monitoring is limited to North America. Preliminary results show the GOES values are comparable to amounts from the Total Ozone Mapping Spectrometer and ground-based measurements.

Land Surface Parameters for Use in Weather Forecast Models. Satellite-derived fields of land surface characteristics are being produced operationally for use in NWP models. These include radiation products delivered in near, real-time as forcing variables; surface characteristics, such as fractional green vegetation and albedo, that specify model lower boundary conditions; and validation quantities, such as surface temperature. These products are meant to help the NWP models maintain better soil moisture fields which in turn results in better near surface temperature and humidity forecasts, and better precipitation forecasts. These fields now include POES-based (SSM/I and AMSU) estimates of surface emissivity, snow cover, sea-ice extent and concentration, land surface skin temperature, and soil wetness. Development of snow depth is underway. Plans are in the making to develop the AMSU-A Snow Water Equivalent (SWE) product for operational use. Forward models for surface emissivity at various microwave frequencies have been developed and are being tested in the forecast models. Algorithms to determine clear sky ice surface temperatures have been developed and delivered to Atmospheric Environment Service, Canada for evaluation. New techniques such as automatic edge detection and incorporation of new sensors such as AMSU and NASA's MODIS are in development to improve operational production of daily snow and ice extent products. These products are delivered as digital files to NWP models and to the NWS Climate Prediction Center and other users. Graphical imagery of operational northern hemispheric snow cover can be found on the Internet at www.ssd.noaa.gov/SSD/ML/real-time.html #SNOW.

Clouds from AVHRR. Within STAR, methods to derive information on cloudiness have been developed and applied to data from the AVHRR. The Clouds from AVHRR Extended (CLAVR-x) system runs within NESDIS and provides information on cloud detection, cloud thermodynamic type, cloud height, cloud opacity and cloud particle size. These products are made at the native AVHRR resolution (1 or 4 km) and are also produced on a global map with a resolution of 55 km. The cloud products from AVHRR have been demonstrated to be consistent with those from more advanced imagers such as MODIS. The AVHRR cloud products are used to verify NWP cloud parameterizations and the AVHRR cloud detection results are used by AVHRR applications that require cloud-free data.

Given its long record (1981-2006) and uniform set of observations, the AVHRR provides a unique data-set for satellite climate studies. In recognition of this, STAR has embarked on a project to generate a new cloud climatology from the AVHRR. The AVHRR Pathfinder Atmospheres Extended (PATMOS-x) is the successor to the PATMOS project. Unlike PATMOS, PATMOS-x will provide a full suite of cloud properties and include data from the AVHRR in the morning orbits and include data from the NOAA-klm satellites. Similar to PATMOS, PATMOS-x will also provide non-cloud products such as aerosol optical thickness and outgoing long wave radiation. This data is being used to study the multi-decal climate variability in the atmospheric parameters within PATMOS-x. The goal of PATMOS-x is to complement the view of clouds provided by other satellite cloud climatologies.

Aerosols. STAR scientists are conducting research that aims at combining historical, current and future satellite-derived aerosol optical depth (AOD) data for identification of possible trends and fingerprints of human influence. The historic AOD data are those derived from AVHRR at NESDIS and are available for the past twenty years. More recent aerosol data are available from the multi-channel MODIS instrument on the current NASA Earth Observing System (EOS) satellites (Terra and Aqua). These aerosol data are retrieved using approaches that are significantly different from the one used operationally at NESDIS. Aerosol properties in NPOESS will be derived from an instrument similar to MODIS and the retrieval will use an algorithm similar to that used with MODIS. In order to infer possible long-term trends and characterize seasonal and interannual variations the new aerosol data sets must be merged with the historic AVHHR record. To facilitate such merging the aerosol data in the Clouds

and the Earth's Radiant Energy System (CERES), Single Satellite Footprint (SSF) data set are being analyzed. The latter data set includes aerosol optical thicknesses obtained by the NASA MODIS algorithm and those retrieved by the NESDIS single-channel retrieval algorithm applied to MODIS/SSF radiances. The analysis has shown that the multi-channel and single-channel retrievals correlate well and yield similar global AOD values when both are available. In both products, a correlation is observed between the retrieved aerosol parameters and ambient cloud amount. The agreement between the two products improves when cloud and surface effects are minimized.

The differences between multi-channel and single-channel aerosol retrievals are also being investigated by applying the NESDIS single-channel aerosol algorithm to the 10-km MODIS reflectances in the MODIS Atmosphere Parameters Subset Statistics (MAPSS) data set, and by comparing the retrieved aerosol optical thickness with those from the MODIS algorithm. This provides a more direct comparison of the two aerosol algorithms over ocean since in this case the radiances used in both algorithms are exactly the same. We find that the single-channel AOD retrievals at the longer wavelength channel are similar to the multi-channel AODs, while the single-channel AODs tend to be larger then the multi-channel ones at the shorter wavelength. The difference seems to depend on the scattering angle.

STAR scientists are participating in the Aerosol Working Group (AWG) of the Global Energy and Water Cycle Experiment (GEWEX) Radiation Panel. One of the goals of AWG is to study various long-term global aerosol products for identifying and quantifying possible trends. So far, five such data sets have been compiled (three from AVHRR, one from Total Ozone Mapping Spectrometer [TOMS], and one from ISCCP-D1 data), and a preliminary comparison of them was conducted.

Aerosol optical depth data are also produced at NESDIS from the geostationary satellites and they are available in the now operational GOES Aerosol and Smoke Product (GASP). Currently, GASP is mainly used for monitoring air quality. The users include universities, and other government agencies (NASA and EPA). GASP supported the New England Air Quality Study (NEAQS) Field Campaign in July 2004. GASP has been updated to use radiances from GOES-12. An extensive evaluation and improvement of GASP is currently underway. Algorithms for aerosol retrieval from the Advanced Baseline Imager (ABI) onboard the future GOES-R satellite are also being developed. The algorithm builds on heritages from the current GOES and MODIS algorithms. Current activities include establishing the relationship between visible and near-infrared surface albedos using atmospherically corrected hyperspectral (Hyperion) observations, and adaptation of time and space dependent aerosol models to supply information needed for a successful retrieval.

Long-term Monitoring of NOAA-15 Advanced Microwave Sounding Unit-A (AMSU-A) Performance. Since the launch of the NOAA-15 satellite, the AMSU-A level 1B data have been captured from the Central Environmental Satellite Computer System (CEMSCS) and stored on optical disks. These data are used for off-line characterization of the instrument radiometric performance on orbit. Over 20 important radiometric parameters are extracted or calculated from the AMSU-A 1B data. NESDIS has already demonstrated that the noise in the observations in all channels is lower (better) than that required by the specifications and, in some channels, it is lower than estimates based on pre-launch test results. NOAA will continue compiling long-term trends of all the parameters to provide a better understanding of the instrument performance. The PC-based software developed for evaluating these data will be improved for better efficiency in processing the data.

Calibration of the Visible and Near-Infrared Channels of the AVHRR. It is very important to characterize and document the in-orbit performance of the AVHRR flown on the polar orbiters. Toward this end, a very comprehensive program of post-launch calibration and characterization of the AVHRR has been implemented to ensure the accuracy, continuity, and viability of the various AVHRR-derived geophysical products, with particular attention paid to the visible and near-infrared channels which do not have any onboard calibration devices. The major program elements are:

•Development of an optimal vicarious post-launch calibration technique, utilizing radiometrically stable calibration sites, model simulations of the radiation measured by the sensors, and simultaneous radiation measurements by the AVHRR and by calibrated spectrometers onboard aircraft;

• Enhancement of available vicarious calibration techniques to improve attainable radiometric calibration accuracies beyond ±5 percent;

• Evaluation of the feasibility of using the International Space Station (ISS) as a platform to calibrate satellite sensors, in general, using radiometers on the ISS traceable to the National Institute of Standards and Technology (NIST);

• Establishment of the AVHRR as a traveling calibration standard to monitor the performance of sensors, such as the imager on the GOES, the visible channel of the HIRS, the Moderate-resolution Imaging Spectrometer (MODIS), and various sensors to be flown on ENVISAT; and

• Design of optimal onboard and vicarious calibration techniques for the

visible and near-infrared sensors planned under NPOESS.

The relevance and importance of these activities has been recognized by the national and international user community, as evidenced by the appreciation and endorsement of the Working Group on Calibration and Validation (WGCV) and the Global Observing Systems Space Panel (GOSSP).

To ensure global access to the results of the AVHRR calibration program, and recognizing the importance of the AVHRR-derived products to national and international programs, such as the International Satellite Cloud Climatology Project (ISCCP), the International Geosphere Biosphere Programme (IGBP), the Global Climate, Ocean, and Terrestrial Observing Systems, and to benefit from sensor calibration research elsewhere, active liaison, and collaboration in some instances, has been established with researchers in NASA, NIST, EUMETSAT, China Meteorological Administration, Beijing, China; Rutherford Appleton Laboratory, United Kingdom; National Space Development Agency, Japan; the NOAA/NASA Pathfinder Program; several space agencies and remote sensing laboratories outside the US, and academia both in the U.S. and abroad.

Calibration of Geostationary Operational Environmental Satellite Instruments. The GOES ground-system calibration processing was modified to accommodate the changes in spectral locations and field-of-view sizes of the Imager channels that became effective with GOES-12. Additional processing changes are being developed to accommodate the further changes that will be made to the Imager on GOES-N. The most notable of these is a tenfold increase in the time the Imager spends viewing its blackbody for calibrating its infrared channels. The increase is intended to improve calibration precision.

On November 24, 2003, the operational calibration processing in the GOES Imager's infrared channels was modified to deal with artificial depressions in measured brightness temperatures that occurred in the hours near local midnight. These depressions, reaching a maximum of approximately 1K (for a scene at 300 K), were most pronounced in the infrared channels at the shortest wavelengths. We believe they were caused by effects of solar heating in the calibration measurements. The processing modification, which invokes a statistical technique to calculate the calibration coefficients near midnight, succeeded in minimizing the artificial brightness-temperature depressions. In addition to calibration, the product processing algorithms for several products will have been modified to accommodate the new channel configuration.

FY 2004 saw considerable progress in the on-orbit calibration of the Imager's visible channel. This channel, lacking an on-board calibration device, can only be calibrated vicariously, i.e., with targets external to the satellite. Here we report results from two such targets. From eight years of observations of a stable Earth target (the Grand Desert in Sonora, Mexico), we estimated that the responsivity of the GOES-8 Imager's visible channel degraded an average of 5.8 percent per year. From routine observations of approximately 60 stars, we estimated visible-channel responsivity degradation of 4.86 0.08 percent for the GOES-8 Imager (from 10/19/95 to 4/1/03) and 5.56 0.18 percent for the GOES-10 Imager (from 1/4/01 to 11/6/03). The difference between the GOES-8 degradation rates from the two methods is a topic of current research.

More information on GOES calibration topics, including the GOES-12 Imager channel changes, the correction for the midnight infrared-channel calibration errors, and the star- and desert-based vicarious calibrations of the visible channel, can be viewed at http://www.oso.noaa.gov/goes/goes-calibration/index.htm

Ocean Surface Winds. Calibration and validation studies are performed by STAR for all new operational ocean surface wind data streams. Product refinement and development activities are currently underway to improve ocean wind vector retrievals in the high wind speed regime, as well as precipitation regimes, where current retrieval algorithms underestimate the wind speeds. There are several satellite-based active and passive microwave sensors planned for launch in the near future from which NOAA would have the opportunity to obtain near,real-time data streams. One of these sensors will be the first demonstration of the passive polarimetric technique, which is being relied on in the NPOESS design to meet the nation's ocean surface wind vector requirements.

High-Resolution Coastal Winds and Storm Signatures from Synthetic Aperture Radar. STAR scientists have developed techniques for deriving high resolution (1 km or less) winds from synthetic aperture radar (SAR) imagery, and are using these derived winds to study ocean surface wind signatures of coastal wind phenomena of atmospheric fronts, hurricanes, and other storms. By sensing variations in ocean surface roughness on the centimeter scale, SAR sensors can image storms, atmospheric waves (such as mountain lee waves), island and mountain wakes and vortex streets, gap flows, atmospheric fronts, and barrier jets. Application demonstrations are currently underway to provide high-resolution winds, imagery, and other SAR-derived products to operational agencies for evaluation. Demonstrations included near,real-time winds for Alaska coastal waters, and SAR-derived hurricane winds. By the year 2007, there will be as many as four wide-swath SAR satellites. If data

acquisition and sharing arrangements can be established to obtain access to SAR imagery from these new sources, frequent routine SAR coverage of U.S. coastal areas will be possible. This increased coverage will allow use of SAR-derived marine and atmospheric products for operational purposes.

Ocean Color. Several programs at STAR are involved in satellite ocean color research. The Marine Optical Buoy (MOBY) Project develops, deploys, and maintains the MOBY off of the coast of Lanai, Hawaii, to measure visible and near,infrared radiation entering and emanating from the ocean. The resulting measurements support the initialization and vicarious calibration of international and national ocean color sensors, such as the Ocean Color and Temperature Sensor, the Sea-Viewing Wide-Field-of-View Sensor, and the Moderate Resolution Imaging Spectroradiometer. The Marine Optical Characterization Experiment (MOCE), MOBY's sister project, involves the collection from ship of in-situ measurements of these and other parameters relevant to ocean color in the surrounding region. Data from both sampling platforms furnish time-series of bio-optical measurements that is employed to track sensor drift, define bio-optical relationships, validate satellite-derived products, and develop ocean color algorithms. In addition to MOBY and MOCE, programs exist at STAR to routinely evaluate the accuracy of NESDIS operational ocean color products and to develop algorithms for remotely detecting and predicting the presence of noxious marine biota, such as harmful algal blooms.

Coral Reef Watch. Like the rest of the world, most of the U.S. coral reef systems are threatened due to pollution, over-fishing, and thermal bleaching. This threat includes almost all of Florida and Puerto Rico reefs, nearly half of Hawaii's reefs, and an unknown, but significant, fraction of reefs in the U.S. Pacific Territories. The widely distributed and isolated locations of many coral reefs preclude normal monitoring practices. Since 1998, NESDIS has used POES satellites to monitor the thermal bleaching stress that leads to coral reef bleaching. Research into the relationship between thermal stress and bleaching resulted in operational web-based products. These include night-time only SSTs and anomalies, and the Coral Reef HotSpot anomaly product (operational in 2002), the Degree Heating Week accumulated heat stress product and Tropical Indices webpage (operational in 2003), and the Satellite Bleaching Alert e-mail system (operational in 2005). Image products have been available to users via the Internet since the program began. Starting in 2006, gridded data products in HDF and Google Earth formats are available via ftp and OPeNDAP servers. This suite of remarkably accurate tools for monitoring potential coral bleaching events has been highly acclaimed by the user community. Operational supports for these coral bleaching products are provided at NESDIS on a 24-hour, seven-day basis. In addition, the Coral Reef Watch (CRW) program provided support to NOAA's Coral Reef Conservation Program as a key player in the emerging global Coral Reef Ecosystems Integrated Observing System (CREIOS) and continues to provide support and solid scientific basis for the development of future monitoring and assessment products and/or capabilities. The Coral Reef Watch alerts proved invaluable to researchers and managers who were able to mobilize resources to assess the record-breaking 2005 Caribbean bleaching event. NOAA Coral Reef Watch is leading an international effort to fully document the extent and severity of this record-breaking event as well as its climatic context.

CoastWatch. NESDIS has responsibility for CoastWatch Program Management. This program is managed in conjunction with other NOAA Line Offices and makes satellite data products and in-situ data from NOAA environmental buoys available to Federal, state, and local marine scientists and coastal resource managers. Data from the Advanced Very High Resolution Radiometer (AVHRR) on NOAA's polar orbiting spacecraft are collected at Wallops Island, Virginia, and at Fairbanks, Alaska. These data are processed on NOAA computers in Suitland, Maryland, using a set of NOAA-developed multi-channel atmospherically corrected algorithms for determination of sea surface temperature. Data are then mapped (Mercator Projection) and sectored to predefined coordinates specified for each of the CoastWatch regions. Digital, high-resolution data products (1 km/4 km in a CoastWatch Binary Format) are then passed daily to CoastWatch Regional Nodes in the eastern U.S. (i.e., Southeast, Great Lakes, Northeast, Gulf of Mexico, and Caribbean). For Regional Nodes in the Pacific region, CoastWatch local data acquisition and processing capabilities are in La Jolla, California; Anchorage, Alaska; and Honolulu, Hawaii. The Internet is used as the primary telecommunications pathway for digital data distribution. Once products are delivered to the CoastWatch Regional Nodes they become immediately available for local use. An ever-growing number of Federal, state, and local organizations are establishing a formal relationship with local CoastWatch Regional Nodes for routine timely access to CoastWatch image products. More information about CoastWatch is available on the Internet at coastwatch.noaa.gov/ COASTWATCH/.

Finally, The Coast Watch AVHRR products are have undergone a modernization effort. These products are now in a new format (HDF) and use new processing software which has

improved the Earth locations of the products. CoastWatch has recently expanded, making available ocean color and ocean surface winds, as well as microwave sea-surface temperature, data and products.

NOAA NATIONAL DATA CENTERS (NNDC)

NESDIS is responsible for the management of the NOAA National Data Centers (NNDC). The NNDCs consist of three data centers: the National Climatic Data Center (NCDC) located in Asheville, North Carolina, the National Geophysical Data Center (NGDC) located in Boulder, Colorado, and the National Oceanographic Data Center (NODC) located in Silver Spring, Maryland (www.nndc.noaa.gov).

The NNDCs were established to be the Nation's primary repository for NOAA data. Since their inception, the role of the NNDCs has expanded in response to the introduction of new technologies useful to the NNDCs and available to the users. Originally designed to archive only NOAA data, the NNDCs now hold environmental data from a variety of sources, to include other U.S. government agencies, such as Department of Defense (DOD) and NASA, foreign governments, universities and cooperatives, and numerous commercial research programs.

The three NNDCs are responsible for the scientific stewardship of the Nation's environmental data and the development and operation of the associated ingest, monitoring, quality control processing, access, archive, analysis and assessment, creation of climate data records (CDRs), and other product generation systems in support of their national and international commitments and users. The NNDCs archive and provide access to numerous types of data. Each type of data provides a unique perspective for use in climate, oceanographic, space weather, and other geophysical research. It is often the combination of many of these data sets that lead to new discoveries and products that support activities, such as weather forecasting, risk (hazards-public safety and economic) mitigation, weather impact assessments, and climate assessments and predictions.

Data sets are typically divided into the method of collection: Remote (Satellites), Airborne, and in-situ (surface: land and ocean). In-situ includes radar, radiosonde, manual and automated surface observing systems, fixed and drifting buoys, etc. Observational data must be accompanied by comprehensive and complete station history data, referred to as metadata, as well as other ancillary and auxiliary documentation describing the data processing procedures (quality control and assurance) used prior to and after archiving the data.

Climate monitoring, evaluation, and prediction are critical to economic sustainability and environmental stewardship. The challenge facing the NNDCs is not only ingesting and processing very large volumes of new data, but also the convenient and timely access to the data and information. Millions of paper pages and thousands of feet of microfilm/microfiche of recorded instrument measurements and other information dating back hundreds of years are currently under the stewardship of the NNDCs. Over the past 50 plus years, many observations have been stored in digital form. There is now in place a program to convert analog records to digital form. The process will take many years to complete.

The development of a new generation of satellites over the next ten years (NASA's Earth Observing System [EOS], the next generation GOES, and NPOESS), the Initial Joint Polar System (IJPS)/Metop, and the enhancement of the operational Next Generation weather Radars (NEXRAD) (dual polarization) present major data management (stewardship and customer access) challenges to the NNDCs.

To meet these challenges, NESDIS has developed the Comprehensive Large Array-data Stewardship System (CLASS) program that will provide a significant portion, but not all, of the funding resources required to improve and maintain the information technology (IT) infrastructure required to support the mandated scientific data stewardship responsibilities for these incredibly large volumes of data.

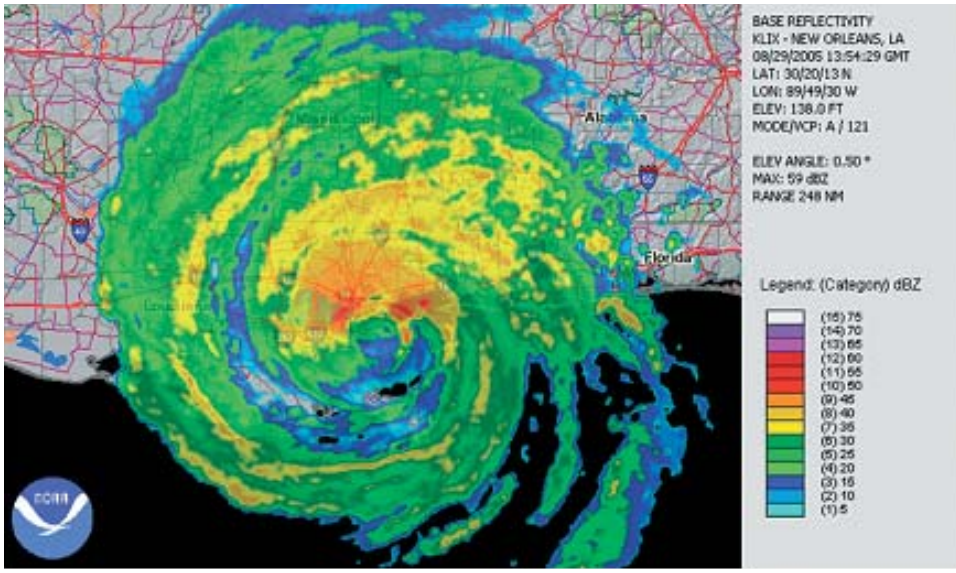


Figure 3-DOC-18. The last Hurricane Katrina image from the New Orleans radar before it lost power.

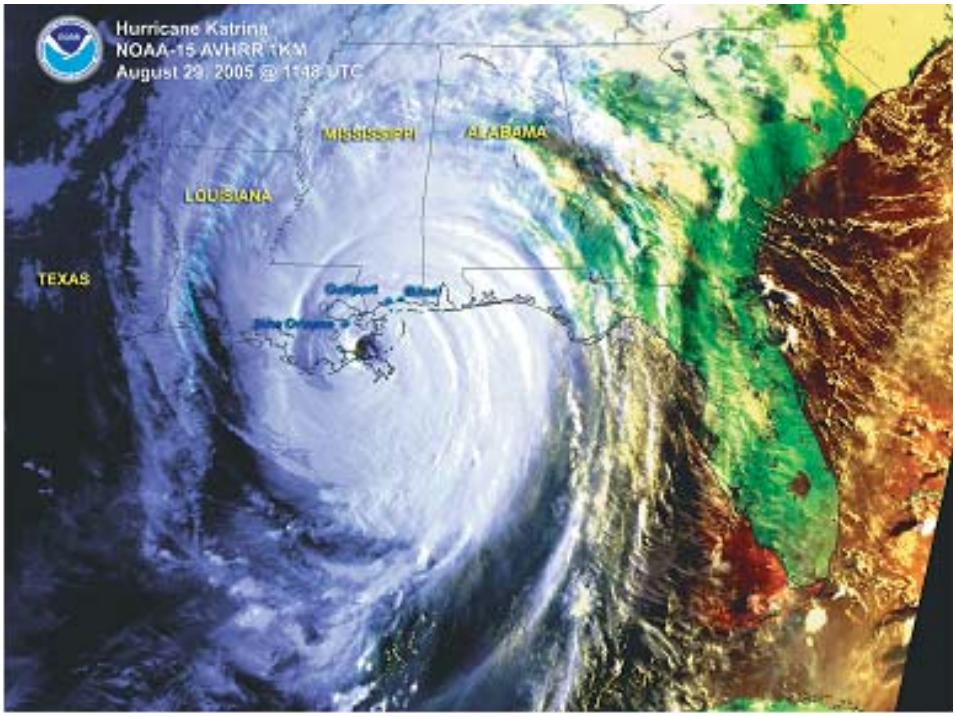


Figure 3-DOC-19. Katrina was one of the strongest storms to impact the coast of the U.S. during the past 100 years.

NATIONAL CLIMATIC DATA CENTER (NCDC)

The National Climatic Data Center (NCDC) is a designated Federal Records Center. It is the officially designated national archive for weather and climate data and information and is the world's largest archive of climate data. NCDC produces and maintains numerous data sets, products, and assessments and services many thousands of customers with data and products worldwide. In addition, NCDC operates World Data Centers for both meteorology and paleoclimatology.

National and global data sets and assessments are produced that support economic and environmental decisions and plans affected by climate variations and change. NCDC describes the climate of the U.S. through monthly and annual State of the Climate reports. NCDC is collocated with the U.S. Air Force Combat Climatology Center and the U.S. Navy Fleet Numerical Oceanography and Meteorology Detachment. These three organizations make up the Federal Climate Complex, fulfilling much of the Nation's climatological requests.

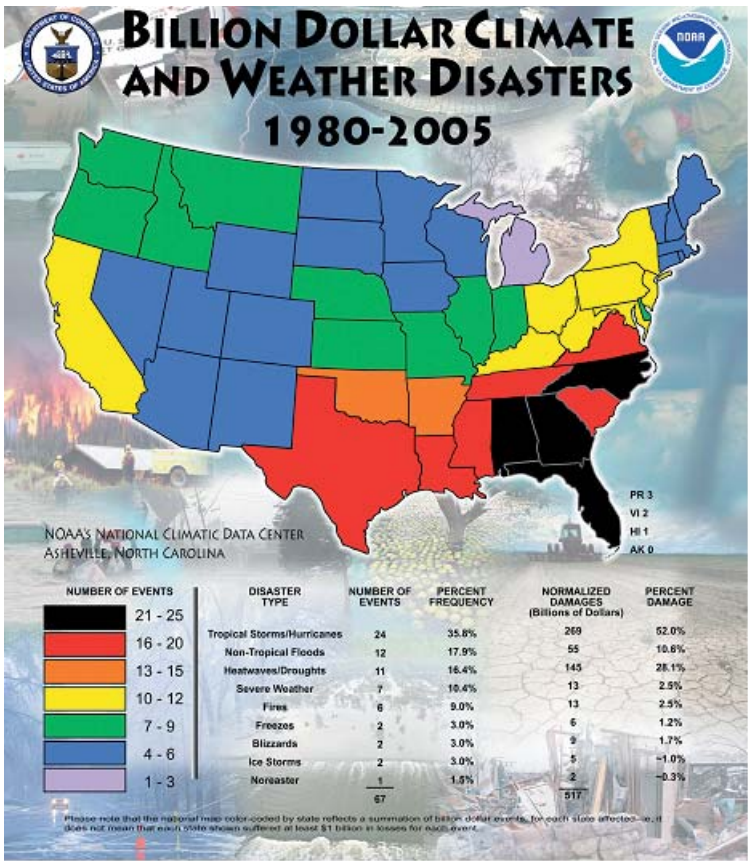
The Vision of the NCDC is: *To be the most comprehensive and accessible source of quality climate and weather related data and information services and to be an objective authority on climate monitoring.*

The Mission of the NCDC is: *To provide stewardship and access to the Nation's resource of global climate and weather related data and information, and assess and monitor climate variation and change.*

The basic functions performed by the NCDC necessary to achieve the mission include: Acquisition (ingesting observations and data) and Quality Assurance Processing, providing Access for new and historical (archived) data, Archiving data and information (long-term data stewardship), and Assessments (climate monitoring).

NCDC is the Nation's "Scorekeeper" in terms of addressing severe weather events in their historical perspective. As part of its responsibility for monitoring and assessing the climate, NCDC tracks and evaluates climate events in the U.S. and globally that have significant economic and societal impacts. Events include drought, hurricanes, tornados, severe storms, flooding, and wildfires.

NCDC is frequently called upon to provide summaries of global and U.S. temperature and precipitation trends, extremes, and comparisons in their historical perspective. Numerous web



DISASTER TYPE	NUMBER OF EVENTS	PERCENT FREQUENCY	NORMALIZED DAMAGES (Billions of Dollars)	PERCENT DAMAGE
Tropical Storms/Hurricanes	24	35.8%	269	52.0%
Non-Tropical Floods	12	17.9%	55	10.6%
Heatwaves/Droughts	11	16.4%	145	28.1%
Severe Weather	7	10.4%	13	2.5%
Fires	6	9.0%	13	2.5%
Freezes	2	3.0%	6	1.2%
Blizzards	2	3.0%	9	1.7%
Ice Storms	2	3.0%	5	~1.0%
Noreaster	1	1.5%	2	~0.3%
	67		517	

Please note that the national map color-coded by state reflects a summation of billion dollar events, for each state affected, so it does not mean that each state shown suffered at least $1 billion in losses for each event.

Figure 3-DOC-20. Billion Dollar Climate and Weather Disasters 1980-2005

pages and reports are available dealing with these events and with the state of the climate in general. (See http://www.ncdc.noaa.gov/extremes.html and http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html).

The U.S. sustained 67 weather-related disasters during the 1980-2005 period in which overall damages and costs reached or exceeded $1 billion at the time of the event. These disasters do not include any events that had unadjusted damages/losses less than $1 billion dollars, but subsequently may have reached $1 billion after applying the Gross National Product (GNP) inflation/wealth index. Fifty-eight of these disasters occurred since 1988, with total unadjusted damages/costs of nearly $380 billion. Seven events occurred in 1998 alone, the most for any year in the summary period, though other years have recorded higher damage totals. (See http://www.ncdc.noaa.gov/oa/reports/billionz.html).

The NCDC developed visualization tools that are used with NEXRAD level II data and NEXRAD level III products. The NCDC NEXRAD Interactive Viewer and Data Exporter load NEXRAD volume scan data and derived products into an OPEN GIS compliant environment. The applications are launched via Java Web Start and run on the client machine while accessing the data remotely from the archive at the NCDC. The NEXRAD Interactive Viewer provides tools for custom data overlays, animations, and basic queries. The export of images and movies is provided in multiple formats. The NEXRAD Data Exporter allows for data export in both vector polygon (Shapefile, GML, Well-Known Text) and raster (GeoTIFF, ESRI Grid, HDF, NetCDF, GrADS) formats. The visualization tools are now part of university course curriculums, have assisted in Space Shuttle upper atmospheric electron distribution studies, are used by the National Transportation Safety Board aircraft accident investigations, are routinely used by government and university researchers, and are being used by other countries.

Operational Programs.

The NCDC operational programs include:

• Long-term stewardship (archive and access) of the Nation's weather and climate data, as part of the Federal Records Retention System. The NCDC is an approved Agency Records Center and operates under the National Archives and Records Administration Federal Records Center guidelines and policies for managing weather and climate data records and information.

• Scientific Data Stewardship functions inherent to the mission of the legislatively designated Nation's Climate Data Center. These include developing and operating the associated ingest, monitoring, quality assessment processing, access, archive, analysis and assessment, creation of climate data records, and other product generation systems in support of national and international commitments.

• National partnerships with Federal agencies (such as the National Aeronautics and Space Administration, Department of Defense, Environmental Protection Agency, Department of Agriculture, Department of Energy, Department of State, National Science Foundation, U.S. Geological Survey, U.S. Global Climate Research Panel), many state agencies, all NOAA Line Offices, Regional Climate Centers, State Climatologists, universities, and many others. These partnerships contribute to the collection, quality assurance processing, and access to regional and national observing networks, to climate monitoring, to the national climate assessments, and to a National Climate Services Program.

• International partnerships with the World Meteorological Organization, International Council of Scientific Unions, World Data Centers, Intergovernmental Panel on Climate Change, UNESCO, and other nations through bilateral and multilateral agreements. Examples are the World Data Center for Meteorology (archiving the data collected by internationally sponsored research programs and actively exchanging climate data with foreign countries to support research and other activities) and the World Data Center for Paleoclimatology (assembling, archiving, and providing access to global paleoclimatic data derived from worldwide tree-rings, stalactites and stalagmites, coral samples, pollen and macro-fossils, lake and bog sediments, marine sediments, ice cores, and other geological and biological sources).

• Maintaining and updating national and global baseline data sets and climate data records that are used for monitoring, evaluation, analyses, and assessments of climate variation and change on global and regional scales. Examples of these data sets include the Global Historical Climatology Network, the U.S. Historical Climatology Network, the U.S. Climate Reference Network, the Comprehensive Ocean-Atmosphere Data Set, the Comprehensive Aerological Reference Data Set, and the Monthly Climate Data of the World.

• Customer Service. Customers can access data, information, and products through a variety of means, such as real-time and near,real-time digital access and retrieval of new and archived historical observations through E-Commerce web enabled capabilities (Internet), as well as through traditional methods, i.e., telephone, e-mail, , facsimile, and traditional post. Digital access, retrieval, and delivery of data on-line and in a robotic storage system via the Internet is the primary and preferred customer service capability. Data and information can also be delivered on magnetic media (tape and disk), hard copy (paper and microfilm), electronic downloads, and staged for FTP trans-

fers. Many of the NCDC assessments, peer reviewed journal articles, published papers, and conference reports are also available on-line.

• Climate Data On-line (CDO) System. The CDO system is NOAA's primary means for distributing and providing access to in-situ climate data. CDO includes both recent and historical data, useful for studies of particular weather events and for historical analysis of data for statistical and other research purposes. The general types of data currently included in the system, which continues to be populated, are surface hourly, daily, and monthly data, hourly precipitation data, and 15-minute precipitation data. As data integration efforts continue, the system will be greatly expanded to include numerous additional stations and data types. There are two methods to access climate data within CDO:

• The CDO homepage (http://cdo.ncdc.noaa.gov). This provides numerous search and retrieval mechanisms, such as by region, country, state, climate division, county, and station; for any required times series.

• The GIS interface (http://www.ncdc.noaa.gov). Click on "search by map" on the left-hand side bar. The GIS tool-set provides an array of methods to select regions and locations of interest, to overlay various layers of information, etc.

Supporting Research.

The NCDC engages in an active research program to support the operational programs.

• Scientific Data Stewardship Program. This program provides an approach to maximizing the performance, quality, and utility of climate observing systems, data, and information so that the scientific integrity and long term utility of climate records for a broad range of users will be ensured. Five fundamental principles provide the framework for this program:

• Ensure Observing System quality during the design phase and real-time monitoring of performance;

• Develop an end-to end Climate Processing System that includes the timely ingest, quality assurance processing, immediate access to new and long-term access to historical records, and the long-term safeguarding of the climate records for future generations;

• Provide basic Information Technology (IT) support;

• Document Earth System Variability through monitoring and evaluation of present, future, and past observations; and

• Enable and facilitate future research through periodic analysis and assessment of new and historical records.

• Digital Health of the Network Monitoring (Observing System Performance Indicators). The purpose of the network monitoring process is to improve the quality of new observations and the fidelity of the historical archives by providing real-time information on the health and status of NOAA's observing networks. The fully developed system will continually monitor and assess the state of these networks with the intent of providing feedback that could either lead to improvements in the network or changes in analysis techniques to account for problems in the network. Anomalies and systematic performance problems are evaluated and reported to the network manager. The outcome will be improved observing system performance and higher quality data records. In most cases, these data quality issues can be identified and corrected before the data are incorporated into the historical archives and associated databases. The COOP Observing Network, the U.S. Climate Reference Network (USCRN), the Automated Surface Observing System (ASOS), and the Global Climate Observing System Surface Network (GSN) and Global Climate Observing System Upper Air Network (GUAN) are regularly monitored and the plan is to add other networks. The USCRN program has a more rigorous operational daily monitoring system of hourly performance (see http://www.ncdc.noaa.gov/oa/hofn/global-insitu.html).

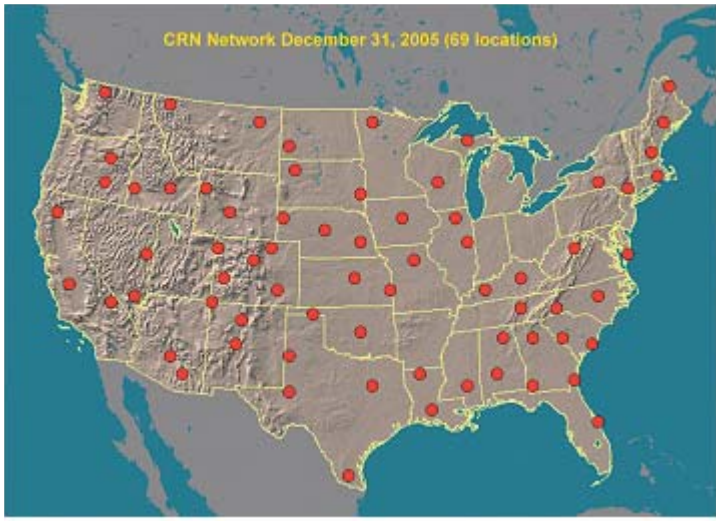


Figure 3-DOC-21. Current Climate Reference Network Site Locations

• Assessments and Reports. A series of regular reports are released regarding several key climate issues of concern to the nation. For example, the NCDC releases a monthly and annual State of the Climate for the U.S. and the North American Drought Monitoring Report which is a collaborative effort between Canada, Mexico, and the U.S. (See http://www.ncdc.noaa.gov/oa/climate/research/monitoring.html). Continuing study of the identification and blending of key parameters from satellite, radar an in-situ observing systems will lead to a new generation of quality climate data records. Understanding and knowledge, as well as new products and serv-

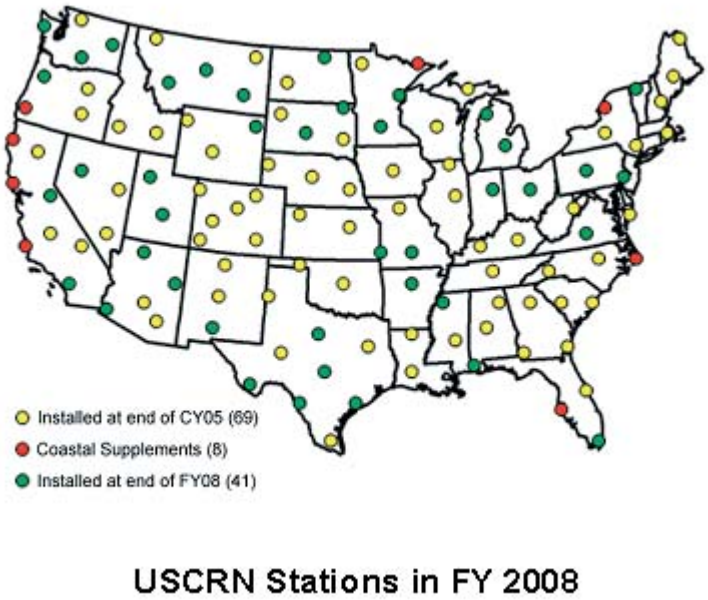


Figure 3-DOC-22. USCRN Stations in FY 2008

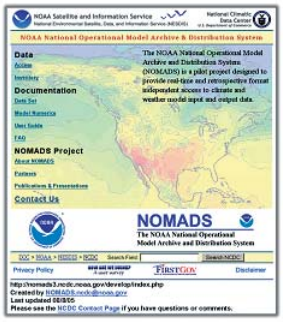
ices for research and practical economic and environmental uses, will be derived from this progressive approach to maximizing the true value of observations.

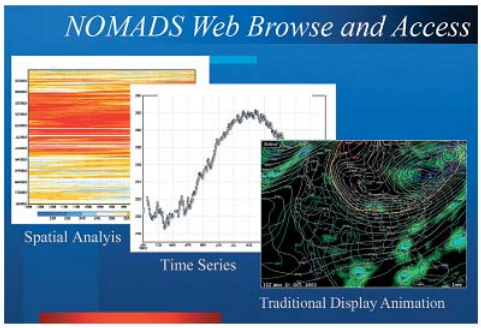
• U.S. Climate Reference Network (USCRN). The Ten Climate Monitoring Principles described in the National Research Council Report, Adequacy of Climate Observing Systems (1999), are being used to guide the design, deployment, and life cycle management of the USCRN. The USCRN is the first U.S. observing system built with the primary purpose of providing climate-quality measurements. Data from the fully deployed network of approximately 110 stations will quantify the variance in surface air temperature and precipitation on a national scale.

The USCRN climate-quality observations avoid the time-dependent biases typically experienced with other surface observing networks. The USCRN is becoming the nation's benchmark network, by providing a standard to which satellite, weather radar, and other surface systems (e.g., Automated Surface Observing System [ASOS], COOP, mesonets, etc.) observations can be validated and verified. In essence, the USCRN is providing the means to enhance the quality and confidence in other observations, as well as contribute to rehabilitating existing historical databases and data sets. This will produce a significant increase in the volume of climate quality data and information that can be used in assessing past climate trends and change, as well as contribute to the present and future climate monitoring, evaluation, and forecast tasks. (See http://www.ncdc.noaa.gov/crn.html)

• NOAA Operational Model Archive and Distribution System (NOMADS). NOMADS is a collaborative approach to provide access and data analysis capabilities for model and other data. The NCDC, in partnership with the National Centers for Environmental Prediction and the Geophysical Fluid Dynamics Laboratory, initiated this project to address a growing need for remote access to high volume Global Climate Model and Numerical Weather Prediction model data. The NOMADS team has partnered with existing and development activities including CLASS, National Oceanographic Partnership Program's, National Virtual Ocean Data System, the Department of Energy's Earth System Grid, and the Thematic Real-time Environmental Data Distributed Services developed through the National Science Foundation. NOMADS uses a distributed client-server framework of data servers together with emerging technologies to access data stored in heterogeneous formats at geographically distributed repositories. NOMADS provides, for the first time, long-term stewardship of numerical and climate model runs and provides the regional modeling community with the data necessary to initialize local models. NOMADS also provides the tools necessary to inter-compare model and observational data sets from around the world. (See http://www.ncdc.noaa.gov/oa/model/model-resources.html)

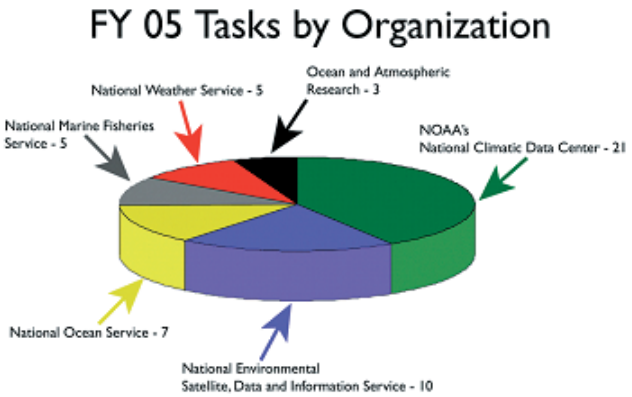
• Climate Database Modernization Program (CDMP). Digital databases of wind speed and direction, precipita-





NOAA Operational Model Archive & Distribution System provides visualization and access to model data

Figure 3-DOC-23. NOAA Operational Model Archive & Distribution System provides visualization and access to model Data.



NOAA tasks supported by the Climate Database Modernization Program

Figure 3-DOC-24. NOAA tasks supported by the Climate Database Modernization Program

tion, temperature, and pressure are far more useful than paper and microfilm records. These databases support many disciplines, including economic research, engineering, risk management, and passive (solar, wind) energy enterprises. The CDMP addresses access and utilization issues. The Program's goal is to make non-digital (paper/film) historical climate data digitally accessible and retrievable on-line via the Internet. The conversion of paper and microfilm records to digital databases and data sets will provide access to either optically scanned images of records or data manually keyed into digital databases. Many of these records are being merged with the more recent digital databases extending the digitally accessible and retrievable time series to many decades, as well as hundreds of years in some cases. Forty million documents have been imaged and many thousands of observations manually keyed or digitized from the merchant and military ship records, America's military forts, U.S. cities, lighthouses, weather ships, and other sources. The sixth year of the CDMP expanded into all NOAA operational line offices. The CDMP provides an unprecedented and unique opportunity to rescue valuable climate and environmental data dating back into the 1700s that are in jeopardy of permanent loss due to the deterioration of the paper and microfilm media (See http://www.ncdc.noaa.gov/oa/climate/cdmp/cdmp.html).

• NOAA Paleoclimatology Program. Paleoclimatic data is an important segment of documenting and reconstructing annual to century scale records leading to climate records dating back 10s and 100s of millennia. The incorporation of this program into the functions and activities of the NCDC enhances the identification and understanding of climate change and variation. The NCDC Paleoclimatology Branch cooperates with many countries in research projects that combine the global paleoclimate database with the instrumental record to extend the climate record back in time for climate model verification and climate change studies. Objectives of the program are to cooperate with researchers in academia, NOAA and other agencies to: conduct original research to describe the global patterns of annual-to-millennial scale climate change, understand the causes of climate change, separate man-induced climate change from natural variability, and validate the models that are used to predict future climates. (See http://www.ncdc.noaa.gov/paleo/paleo.html)

• Comprehensive Large Array-data Stewardship System (CLASS). CLASS is the NOAA implementation program for an improved architecture for archiving and servicing large-volume data. Advances in technology, including faster network access, web-based interfaces, and emerging discovery and analysis tools, will provide a one-stop capability to access the NOAA large array data sets. The CLASS objective is to establish a web-enabled browse, order, and retrieval delivery system that will enhance and increase the availability and accessibility of satellite, radar, and other data and derived products to customers worldwide. The CLASS integrated storage and web-based access and servicing system design incorporates many of the features and capabilities of the current Satellite Active Archive system built for the POES data stored on a robotic system located in Suitland, MD. The CLASS program has established dual sites, one in Asheville, NC, and another in Suitland, MD. There are plans to move the Suitland site to Boulder, CO. A third CLASS site is also slated for Fairmont, WV. NOAA Polar-orbiting Environmental Satellite (POES) and Geostationary Orbiting Environmental Satellite (GOES) data are currently available via the CLASS interface. CLASS data and product enhancements will be implemented in phases called campaigns. New major campaigns planned include NEXRAD, National Polar-orbiting Environmental Satellite System Preparatory Program (NPP), National Polar-orbiting Operational Environmental Satellite System, Earth Observing System Long Term Archive, and the European Meteorological Operational Satellite Program (see http://www.class.noaa.gov).

• Air Quality Forecasts. NCDC archives NOAA's Air Quality Fore-

casts. The Air Quality Forecasts are forecast guidance of one-hour and eight-hour averaged ground-level (surface) ozone concentration. The guidance is produced twice a day, for hourly intervals through midnight on the following day (48 model hours), seven days a week for the northeastern U.S. initially, and then gradually will include the entire U.S. by 2009. NWS provides the data. These data provide ground-level ozone forecast guidance for state and local air quality forecasters and help the public limit adverse effects from poor air quality. This forecast guidance helps meet a congressionally directed national air quality forecast capability. These data will have received a high measure of quality control through computer and manual edits.

NATIONAL OCEANOGRAPHIC DATA CENTER

The National Oceanographic Data Center (NODC) (www.nodc.noaa.gov) manages the world's largest collection of publicly available oceanographic data. NODC holdings include in-situ and remotely sensed physical, chemical, and biological oceanographic data from coastal and deep ocean areas. NODC customers reuse this data to answer questions about climate, ocean, and coastal phenomena.

NODC also operates NOAA's Central and Regional Libraries. These libraries provide environmental references services that support NOAA research and other technical information retrieval services to NOAA staff; and maintain the official archives for NOAA documents.

Internationally, NODC hosts the World Data Center for Oceanography, Silver Spring under the auspices of the International Council of Scientific Unions and the U.S. National Academy of Sciences.

NODC supports ecosystem stewardship through the National Coastal Data Development Center (NCDDC) in Stennis, Mississippi by providing access to the nation's coastal data resources. NCDDC achieves this capability through the integration of diverse coastal data distributed in multiple repositories and provides these data to users via the Internet using established and emerging technologies. They provide a searchable metadata catalog of coastal data, developing gateways to data repositories and using middleware technology that provides data in user specified formats.

Specifically, NODC data archive and access responsibilities support climate research and operational ocean observing system activities. NODC performs ocean profile data management for internationally coordinated global ocean observing systems such as the Argo Ocean Profiling Network and the Global Temperature-Salinity Profile Program (GTSPP) in cooperation with applicable JCOMM committees. NODC's objectives are

- To safeguard versions of the Argo and GTSPP near,real-time and retrospective data and information, and
- To provide high quality data to a wide variety of users in a timely and useful manner.

The Argo and GTSPP data system present an excellent opportunity to improve ocean and climate forecasting, with consequent benefits for the protection of life and property and effective planning for the effects of seasonal to inter-annual climate variability.

NODC produces regular updates of the World Ocean Database and World Ocean Atlas. The most recent version, 2001, includes over seven million profiles of scientifically quality controlled ocean temperature, salinity, oxygen, plankton, pigment, and nutrient data. The Atlas presents statistics and objectively analyzed fields for one-degree and five-degree squares generated from World Ocean Database 2001, observed and standard level flagged data. The ocean variables included in the atlas are: in-situ temperature, salinity, dissolved oxygen, apparent oxygen utilization, percent oxygen saturation, dissolved inorganic nutrients (phosphate, nitrate, and silicate), chlorophyll at standard depth levels, and plankton biomass sampled from 0 - 200 meters depth. Further information on both products is available at: www.nodc.noaa.gov/OC5/indprod.html.

The NOAA Marine Environmental Buoy Database (http://www.nodc.noaa.gov/BUOY/buoy.html) is one of the largest and most frequently used data archives maintained by the NODC. This database holds wind, wave, and other marine data collected by the NOAA National Data Buoy Center (NDBC) from moored buoys and C-MAN (Coastal-Marine Automated Network) stations. Parameters reported by both buoys and C-MAN stations include air temperature and pressure, wind speed and direction, wind gust, and sea surface temperature.

NODC is developing a capability to provide public access to consistently-processed, climate-capable satellite datasets and applying them to various scientific problems. The first products provided in 2003, were Pathfinder reprocessed 9 km and 4 km sea surface temperatures. For further information see www.nodc.noaa.gov/sog/.

The National Coastal Data Development Center (NCDDC) manages the Coastal Data Development (CDD) program. The focus of NCDDC is to improve the quality of web-based search and access tools and implement web-based access to priority data sets from Federal, state, and local repositories. Geospatial display capabilities have been added that allow the user to link the data to coastal imagery, charts, bathymetry to obtain a complete data picture of the ecosystem of interest.

To identify priority data sets, NCDDC coordinates with Federal, state, and local agencies, academic institutions, non-profit organizations

and the private sector to create a unified, long term database of coastal data sets available from a variety of sources. The NCDDC develops and maintains a catalog of available coastal data, builds gateways to these sources, ensures the equality of the metadata, populates and updates the databases, and provides on-line search and access and geospatial display for the coastal user community.

The CDD program supports NOAA's Ecosystem strategic goal which aims to build the capacity of Federal, state, local, and international managers to make decisions that protect, restore, and use coastal ecosystem services. The Earth's coastal ecosystems are home to a wealth of natural resources, and the lives and livelihoods of people are linked to these national treasures. Sustainable growth of our coastal regions is critical to our economy by supporting commercial and recreational fishing, waterborne commerce, home construction, and tourism. Base activities aim to advance understanding and predict changes in the Earth's environment to meet the economic, social, and environmental needs of the U.S.. This supports the strategic goal of the Department of Commerce to, "*Observe, protect, and manage the Earth's resources to promote environmental needs*."

NOAA/NODC Library

NODC houses the NOAA Central Library (www.lib.noaa.gov/) which supports weather and climate research programs by providing a variety of information services, including:

- Access to print and electronic versions of American Meteorological Society journals.
- Access to Meteorological and Geoastrophysical Abstracts (desktop access at the Silver Spring campus).
- Desktop access to Web of Science at several NOAA sites.
- Assistance in obtaining site licenses for 169 National Weather Service field sites for electronic access to Monthly Weather Review and Weather and Forecasting.
- Archival of historic collections of the Weather Bureau.
- Data rescue of hundreds of volumes of meteorological data publications in danger of loss.

NATIONAL GEOPHYSICAL DATA CENTER

National Geophysical Data Center (NGDC) (www.ngdc.noaa.gov) staff archive, assess, and provide access to satellite and ground-based observatory data from national and international programs supporting research in meteorology, climatology, and space weather as well as solar-terrestrial physics, snow and ice, marine geology and geophysics, and solid Earth geophysics. The National Snow and Ice Data Center (NSIDC), at the University of Colorado, is an affiliated partner with NGDC. World Data Centers for Solar-Terrestrial Physics, Marine Geology and Geophysics, Glaciology, and Solid Earth Geophysics under the auspices of the International Council of Scientific Unions are operated by the two national centers. Research activities focus on satellite remote sensing to assess the long-term changes of the land surface, the space environment, snow cover and sea ice.

Long-term archive responsibilities for the nation are provided by NGDC activities. NGDC maintains the nation's archive for global tsunami and related hazard events. This includes tsunami events, triggers, run-up locations and heights, damage descriptions and photographs. This information is essential for researchers focusing activity on at-risk areas. As part of NOAA's effort to improve tsunami research and warning, NGDC has established a long-term archive for ocean bottom pressure and Deep-ocean Assessment and Reporting of Tsunamis (DART) data. NGDC also manages the sole archive of space weather data from GOES, POES and DMSP satellites. NGDC maintains the only archive of raw data records and visible and near-infrared imagery collected on DMSP satellites for meteorological, oceanographic and Earth surface studies. The space weather ground-based archives focus on data used in NOAA's space weather forecasts, warnings and alerts. NSIDC manages cryospheric data from both ground-based and satellite instruments. These data stewardship and scientific stewardship activities for satellite and ground-based data include processing, management, analysis and quality assessments.

Online WWW-based access services to these large databases continue to evolve at NGDC. Data discovery, browsing, and delivery are fairly mature functions. Data directories are managed by relational database management systems available to most search engines. Almost all of the data sets reside in robotic libraries and are accessible online, however some data sets are easier to browse, display and use than others. NGDC uses Web map-based access to the integrated hazards databases. Users can select events either through a geo-referenced map interface or via traditional search and retrieve engine. NGDC has several projects as part of the NESDIS program to digitize and make accessible the most important records in the huge historical archive. Interactive displays of multi-disciplinary data sets and data mining are under development and NGDC has embarked on an environmental scenario generator project to mine information from the archives and to use the mined information to launch numerical simulations of the atmospheric and space environments.

The DMSP activity prepares calibrated and geo-referenced records from the raw data records recorded by the scientific instruments on DMSP satellites. Data sets include visible, infrared and microwave imagery,

microwave soundings and in-situ measurements of the space environment. User services are provided through the Space Physics Interactive Data Resource (spidr.ngdc.noaa.gov/spidr/). Research activities focus on the use of the nighttime visible and infrared imagery from the DMSP Operational Linescan System (OLS). The nighttime lights product has been used to assess changes in power consumption both regionally and globally over the period 1992 to present. Nighttime lights have been used to support humanitarian relief services after natural disasters such as Hurricanes Wilma and Katrina.

GOES, POES and DMSP satellite data of solar activity and the near Earth space environment managed by NGDC provide the long-term monitoring of space weather conditions. These data record the Earth's magnetic field, the electrically charged environment, and solar x-rays from geosynchronous and polar sun-synchronous altitudes. Data from ground-based observatories recording solar activity, ionospheric characteristics and geomagnetic variations complement, enhance and provide ground truth for the satellite measurements. The Solar Geophysical Data bulletin containing solar and space weather data is published monthly. The space weather program at NGDC archives measurements of total solar and solar spectral irradiance for use in climate studies (http://spidr.ngdc.noaa.gov/spidr/). Tabular listing of ionospheric parameters and ancient solar images are part of the digitizing and access program.

National Snow and Ice Data Center

The National Snow and Ice Data Center (NSIDC) at the University of Colorado, which is affiliated with NGDC, manages several cryospheric-related data archives of interest to meteorology and climatology. These data sets include a collection of historical photographs of glaciers, temperature, pressure and position data from drifting buoys placed on the central Arctic pack ice and data from the NOAA snow cover and DOD-NOAA sea ice chart digitizing projects. NSIDC provides data management services for a variety of cryospheric research programs sponsored by NASA and NSF. In addition, NSIDC has developed gridded sea ice products (sea ice concentrations and multi-year ice fraction) based on passive microwave data collected by NASA and DMSP satellites (see Figure 3-DOC-24). NSIDC is acquiring snow cover, glacier and sea ice records from the former Soviet Union. Online services are available at www.nsidc.colorado.edu.

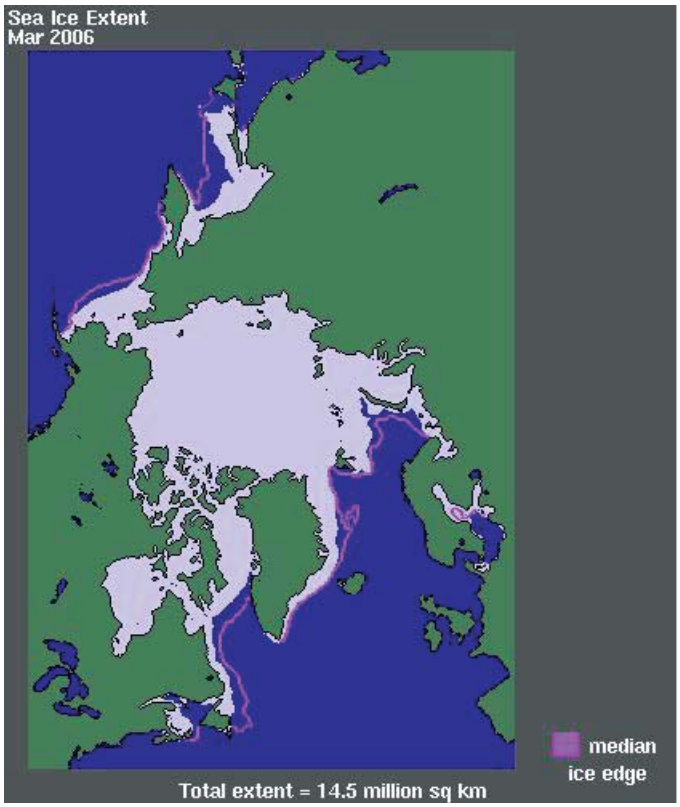


Figure 3-DOC-25. This image, from the NSIDC Sea Ice Index, shows the extent of Arctic ice in March (grey area) relative to the normal position (based on a reference period of 1979 to 2000), shown by the pink line. March is the month of greatest Arctic ice extent. While scientists have known of the decline in summertime ice extent for years, the statistically significant negative trend in winter ice extent is a new phenomenon. Scientists and the interested public can tract ice trends at nsidc.org/noaa/seaice_index/.

Supporting Research

Natural Hazards Reduction. Severe tsunami events are relatively rare and frequently the first reaction to a serious event such as the 26 December 2004, Indian Ocean tsunami is to clean-up the damage. A global database of past tsunami events, run-up heights, death and damage descriptions, and photographs is an essential research tool when identifying at risk areas and likely damage from modeled events. NGDC maintains the nation's global tsunami event database. In FY 2006 NGDC reviewed and documented 60 percent of events with the global tsunami database classified as significant, including the locations and magnitudes of the source events, maximum runups and total effects. As an associated activity, NGDC in FY 2006 established a web-accessible archive of tsunami program Deep-ocean Assessment and Reporting of Tsunami (DART) Buoy and Bottom Pressure Recorder (BPR) historical data. These historical records provide the baseline against which real-time measurements can be compared to assess the threat posed by tsunamis (see Figure 3-DOC-25 and http://ngdc.noaa.gov/seg/hazard/DARTData.shtml)

Environmental Remote Sensing. Operational meteorological satellite systems provide a unique opportunity to monitor features on or near the Earth's surface, sometimes on a nightly basis. The DMSP nighttime imagery are used to locate sources of visible

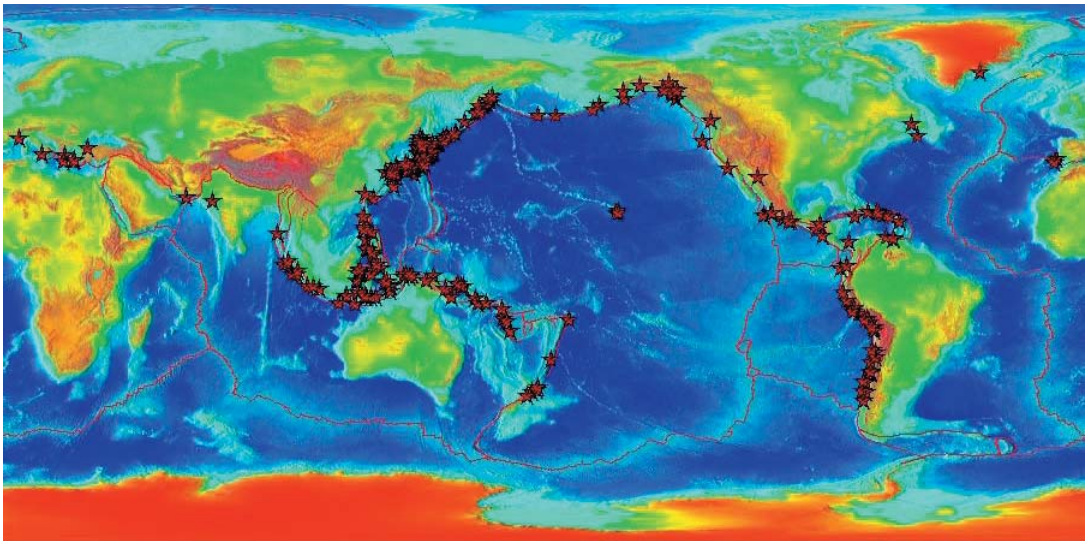


Figure 3-DOC-26. Global distribution of significant tsunami events occurring between 1410 and 2004.

and infrared emissions including city lights, lightning, wildfires, flaring gas, and fishing boats. Research projects use the city lights to infer such diverse parameters as population density, economic vitality, and carbon dioxide emissions. More information is available at dmsp. noaa.gov/ dmsp.html.

Wildfires Monitored from Space. DMSP OLS imagery offers a unique opportunity to monitor wildfires because each satellite records night-time visible emissions covering the entire globe each day. Instruments designed to detect clouds also see wildfires--many of which burn in very remote areas. NGDC has developed a unique capability to capture the night-time emissions from both large and small wildfires. The system has been used to assist the NOAA Operational Significant Event Imagery team and by firefighters in developing countries. More information is available at dmsp.noaa.gov/dmsp.html.

Space Weather. The Space Weather program at NGDC is dedicated to the long-term archive and analysis of NOAA's space weather data. This year marks the completion of a 15-year space weather climatology, covering the ionosphere, thermosphere and inner-magnetosphere. The project, which is designed similarly to the NCEP/NCAR re-analysis project, provides the user community with a uniform view of key space weather domains. In the coming years, analysis of this data will allow for tracking of changes observed in the near-Earth space environment (see Figure 3-DOC-26).

Cryospheric Research at NSIDC. NSIDC's research interests cover a broad spectrum of climate-cryosphere interactions using a variety of observing techniques with special emphasis on arctic regions and satellite-borne instruments. Research projects within NSIDC study the long-term record of snow and ice in polar and mountainous regions, as well as the hydrology of the southwestern US. Algorithms to detect snow, frozen ground and sea ice in passive microwave images from DMSP and NASA satellites have been developed at NSIDC.

Other research includes developing models of the physical and mechanical properties of snow and ice in glaciers and the freeze-thaw cycles of soils in polar regions (the latter is an important component of hydrological modeling). Another area of special interest and study is the interaction between sea ice and the ocean and atmosphere. More information is available at http://nsidc.org/.

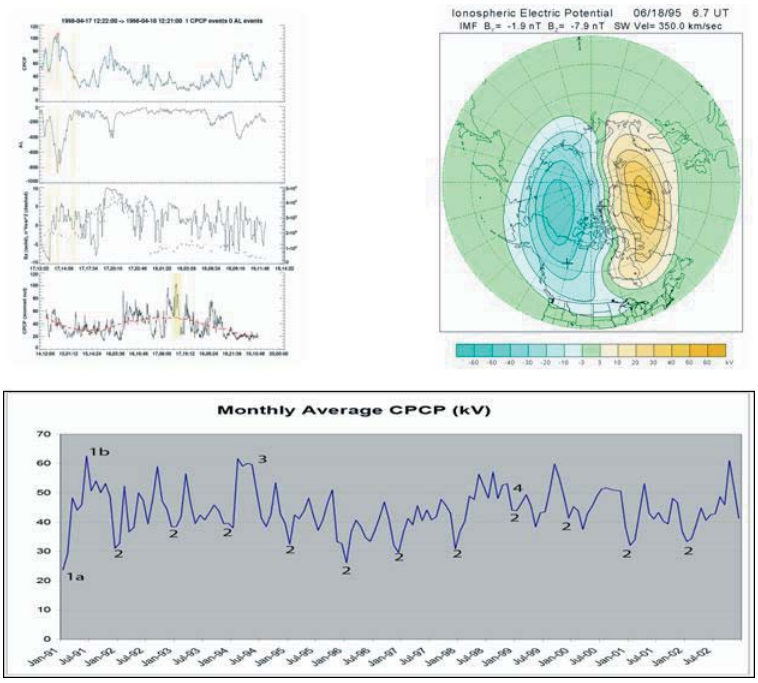


Figure 3-DOC-27. 15-year record of the near-Earth space environment obtained by coupling observational space weather data with physics-based numerical models.

Programs within the Oceanic and Atmospheric Research (OAR) Laboratories support various National Oceanic and Atmospheric Administration (NOAA) meteorological and oceanographic missions. The activities of OAR laboratories provide the innovative ideas needed to improve our understanding of atmospheric, oceanic, and climate science and develop the practical solutions, tools, and techniques that form the basis of improved ocean, weather, water, and climate services. In an effort to make OAR's meteorological, oceanographic, and climate research more extensible, OAR recently re-organized its laboratories in Boulder, Colorado. The new Earth System Research Laboratory (ESRL) consists of four Divisions: Chemical Sciences Division (CSD), Global Monitoring Division (GMD), Global Systems Division (GSD), and the Physical Sciences Division. These divisions were formed in the consolidation of the former Aeronomy Laboratory, Climate Diagnostics Center, Climate Monitoring and Diagnostics Laboratory, Forecast Systems Laboratory, and the Environmental Technology Laboratory. A portion of the former Environmental Technology Laboratory has now transferred to the University of Colorado as the Center for Environmental Technology (CET).

In an effort to improve national resiliency and better protect lives and property, OAR places special emphasis on improving severe weather, flood, and hurricane warnings and forecasts and on improving the utilization and dissemination of data and information. Severe weather events include flash floods, strong winds, thunderstorms (including tornadoes, lightning, and hail), heavy snowstorms, extreme cold and heat, drought, and geomagnetic storms. OAR also places emphasis on enhancing our understanding of the global climate system and improving regional decision support tools for climate and weather.

Key contributions to improved hurricane forecasts fall under the "Hurricanes at Landfall" (HL) focus of the U.S. Weather Research Program (USWRP), the funding for which resides in NOAA's National Weather Service (NWS), and the implementation of which is in OAR. They include more accurate prediction of track, intensity, surface winds, rainfall, improved communication of hurricane forecast information, and improved understanding of human impacts. Improving flood forecasts fall under the component of USWRP labeled "Improving Quantitative Precipitation Forecasting." In pursuit of improved utilization and dissemination of data, the OAR laboratories conduct both in-house and cooperative research with other NOAA organizations, government agencies, joint institutes, universities, and the private sector. In addition, OAR laboratories conduct research to improve routine weather forecasts and improve the ability to forecast regional air quality and atmospheric deposition.

A significant focus of OAR in the weather and air quality area is the development of operational testbeds under the auspices of the USWRP. These testbeds are the mechanism through which research is transitioned to operations. It is recognized by the USWRP that since NOAA is one of the forecast mission agencies in the program, and the program goals are predominantly operational ones, its most significant role in the USWRP is to provide the infrastructure and capabilities to efficiently and effectively test research products in an operational environment. The testbeds are the Joint Hurricane Testbed, the Developmental Test Center (http://www.dtcenter.org/), and the Joint Center for Satellite Data Assimilation (http://www.jcsda.noaa.gov/). These testbeds are operated in partnership with other USWRP agencies. OAR's role is to provide directed research and operational testing, in partnership with the NWS. In addition, the Weather Research and Forecasting (WRF) community model (http://www.wrf-model.org/index.php), also under the auspices of the USWRP, provides a common modeling structure to be shared by most of the testbeds and between the research and operations communities. Several OAR laboratories are involved in the WRF development in partnership with the NWS and other USWRP agencies.

In 2004, the USWRP established the Collaborative Program on the Societal Impacts and Economic Benefits of Weather Information or Societal Impacts Program (SIP) for short (http://www.sip.ucar.edu/). Its mission is to be a clearing house for socioeconomic information on weather, to increase knowledge among the weather community concerning the human and economic impacts of weather, to better determine the value of weather information, and to improve our ability to communicate weather information to all public and private sectors. Within the SIP is a Hurricane Working Group, consisting of the top social scientists, economists, and meteorologists in the U.S. who have worked in the area of hurricanes. They have developed an agenda for

social science research for hurricane forecasts and warnings (http://www.sip.ucar.edu/hurricane.jsp).

In 2004, the World Meteorological Organization established THORPEX: A Global Atmospheric Research Program (http:// www.mmm.ucar.edu /uswrp/programs/nathorpex.html, from which one can link to the international THORPEX website). Currently twelve countries are participating. In the U.S., NOAA is the lead agency and participating agencies include NASA, NSF, and the Navy. THORPEX is a 10-year international global numerical weather prediction program to accelerate improvements in one to 14-day forecasts of high impact weather. In NOAA, OAR, NWS, and NESDIS participate in THORPEX with the Joint Center for Satellite Data Assimilation as a key component. In NOAA, the THORPEX program is developing global ensembles of model predictions and ensembles of ensembles such as the North America Ensemble Forecasting System (NAEFS) in collaboration with Canada and Mexico, which is now being operationally tested at NWS's National Centers for Environmental Prediction's Environmental Modeling Center. The THORPEX funding in NOAA resides in the NWS and is administered by OAR.

OBSERVING TECHNOLOGY

Meteorological, oceanographic, and climate research requires a strong network of observing systems providing data and information and consistent advancements to our observational capabilities. In support of NOAA's mission, OAR supports the advancement of our observing technology through the development and testing of new observing systems, observation techniques, and data ingest and dissemination systems. All OAR observing technology research supports the Global Earth Observing System of Systems (GEOSS) and further establishes OAR as a preeminent leader in meteorological, oceanographic, and climate research.

Numerous OAR laboratories and their related academic and private sector partners are heavily involved in developing new environmental observing system technologies. The Global Systems Division (GSD) of the Earth System Research Laboratory (ESRL) in Boulder, Colorado, takes promising new scientific and engineering technologies from the research arena, helps develop them into mature engineering systems, and transfers these technologies to NOAA operations and the private sector. The Physical Sciences Division (PSD) of ESRL applies and evaluates new remote-sensing concepts and systems. The National Severe Storms Laboratory (NSSL) in Norman, Oklahoma, both develops new remote sensing systems and assists in the transfer of these technologies to the NWS. The Atlantic Oceanographic and Meteorological Laboratory (AOML) in Key Biscayne, Florida, develops, deploys, and manages in-situ oceanographic observing systems across the global oceans. This environmental research, development and associated transition of products and services directly support the Nation's forecasting and warning services.

GSD is investigating the use of superpressure balloons in the stratosphere as a platform for monitoring and observing the environment. Among the balloons' capabilities would be atmospheric soundings. The trajectory of the balloons could be controlled to some extent by adjusting their altitude so as to take advantage of the vertical shear. The balloons would carry compact, lightweight sondes whose locations could be tracked as they fell toward the surface. The balloons would comprise a moderately priced global system.

A number of engineering tests have already been performed at altitude by piggybacking on a zero-pressure balloon launched by the Physical Science Laboratory at New Mexico State University and with launches near the Oregon coast. Telemetry was received line-of-sight from a distance of over 200 miles, the storage batteries were charged by solar panels, the proper thermal environment was maintained during the daytime heating cycle, and the instrument package was successfully recovered after descent by parachute.

GSD is also taking a leadership role in implementing the International Earth Observation System includes the development and testing of Unmanned Aircraft Systems (UAS, formerly referred to as UAVs) for providing global weather and climate observations. The GSD is one of several NOAA Research laboratories collaborating with NASA in support of this project. The goal of these missions is to evaluate the utilization of UASs for improved U.S. and global observing. The Altair's integrated sensor package consists of such components as an ocean color sensor and passive microwave sounder developed by the NOAA's PSD, a gas chromatograph and ozone sensor developed by GMD, a digital camera system provided by NASA, and an electro optical infrared sensor provided by GA-ASI. High and medium altitude, long-duration UASs can fly at remote locations in dangerous flying conditions for long periods. This technology provides many scientific benefits such as sustained global high quality all-weather profiles of atmospheric composition (water vapor,

Figure 3-DOC-28. Altair UAS.

aerosol, cloud water and trace gases), and high altitude vertical resolution and profiling. It also offers a rapid response platform for improved high impact weather forecasts at 1-day to 2-week lead times, and better climate change detection, attribution, and prediction in support of policy decisions.

PSD and GSD will continue development of new sensors and innovative techniques for combining observing systems synergistically and economically. Efforts include developing tools and techniques to integrate the data from surface-based and satellite-borne profiling systems for more effective use of these data in forecasts. In support of this effort, PSD has an active satellite remote sensing group that uses data from various environmental satellites to study air-sea interaction processes, the global hydrological cycle including water vapor and precipitation, and the Earth's radiation budget.

Icing is a weather hazard that occasionally causes aviation disasters, especially in winter. In-flight icing forms on wings and other exposed surfaces as an aircraft flies through clouds that contain super-cooled liquid water droplets. Leveraging earlier work with polarization-sensitive cloud radars, PSD designed a new ground-based cloud radar and radiometer system to monitor clouds in the vicinity of airports and to provide automated warnings of icing conditions aloft. This instrument is the Ground-based Remote Icing Detection System (GRIDS). In addition, GSD continues to perform research and analysis to improve aviation forecasts.

PSD, in association with the Center for Environmental Technology (CET) at the University of Colorado is developing an airborne Polarimetric Scanning Radiometer (PSR) designed to provide higher resolution measurements of sea state quantities, including surface winds. PSD/CET is also investigating the possibility of measuring soil moisture by L-band radiometers.

Starting in 2003, PSD and GMD have been working together with the Canadian Meteorological Service and Canadian Network for the Detection of Climate Change (CANDAC) to re-establish a new Arctic Atmospheric Observatory at Eureka, Ellesmere Island, Canada, in North East Canada as a part of the U.S. Studies of Environmental Arctic Change Program (SEARCH). The Canadian Observatory is being designed to mirror many of the cloud, aerosol and radiation measurements that are already made at the GMD Baseline Observatory in Barrow, Alaska, that has been in continuous operation for 33 years. . Since North East Canada and Barrow, Alaska are in markedly different Arctic regimes the long-term measurements from these sites will be complementary in providing information to monitor Arctic atmospheric changes. Long-term data from these sites will be used to improve short-term and long-term forecast models, and improve satellite measurement of meteorological phenomena in the Arctic regions. Along with the National Science Foundation, PSD and GMD are helping to refurbish a historic meteorological station and establish an Atmospheric Baseline Observatory at Tiksi, in the Russian Arctic. This would be the first station of this type in a region that spans 75 percent of the Arctic littoral. Meteorological data from this newly re-instrumented site will continue a century of data collection that had deteriorated since the collapse of the Soviet Union, and expand measurements to complement those collected at Barrow, Alaska and Eureka, Canada. The high quality of the data to be soon forthcoming from the Tiksi station should considerably enhance Arctic weather prediction and Arctic climate models.

PSD is engaging in a comprehensive observation program to improve operational weather forecast and planned climate model treatments of boundary layer forcing processes. This work centers on development and application of observing technologies for surface fluxes and key boundary-layer variables (profiles of temperature, humidity, wind, and cloud properties). Ship-based measurement systems have been developed and are now used routinely on NOAA research vessels to investigate model accuracies in the marine boundary layer. Recently, land-based systems have been developed and deployed. One point of emphasis is linking observed cloud properties (obtained with mm-wavelength cloud radars and microwave radiometers) to cloud effects on surface turbulent and radiative fluxes (this approach is termed cloud forcing). Ship-based and satellite retrievals of cloud and flux properties are being used. PSD is compiling a large data base to allow climatologically-oriented studies of model parameterizations. Future plans include expanding the observational capabilities to add scanning mm-radar capabilities for investigation of precipitation initiation (a critical issue in triggering deep convection in model domains).

The PSD satellite applications group has developed new techniques for monitoring atmospheric properties over the ocean surface including air temperature and specific humidity. Retrievals of these quantities were improved through a novel use of satellite atmospheric sounders in combination with passive microwave imaging radiometers. The products are being applied to improved global estimates of the flux of heat between the ocean and atmosphere. PSD is also producing a new satellite-derived sea surface temperature product through the blending of infrared and passive microwave data. The technique takes advantage of the complementary strengths of the two sensor types. The product has significant meteorological applications through its use as an input to numerical weather forecast and cli-

mate models.

The NSSL is known for its development of observational capability, both remote and in-situ, and in particular for its role in the development of the WSR-88D NEXRAD radar. NSSL continues to improve the WSR-88D software algorithms used by the NWS forecasters and is exploring ways to enhance the WSR-88D hardware using dual polarization techniques under the NEXRAD Product Improvement (NPI) activity. NPI planning, guidance, and funding involves NOAA, DOT/FAA, and DOD/Air Force.

Most weather radars, including the WSR-88D NEXRAD radar, transmit radio wave pulses that have a horizontal orientation. Polarimetric radars (also referred to as dual-polarization radars), however, transmit radio wave pulses that have both horizontal and vertical orientations. The horizontal pulses essentially give a measure of the horizontal dimension of cloud (cloud water and cloud ice) and precipitation (snow, ice pellets, hail, rain) particles while the vertical pulses essentially give a measure of the vertical dimension. Since the power returned to the radar is a complicated function of each particle size, shape, and ice density, this additional information results in improved estimates of rain and snow rates, better detection of large hail location in summer storms, and improved identification of rain/snow transition regions in winter storms. The signal processing requirements for dual polarization requires an initial step of deploying a new Radar Data Acquisition (RDA) unit for the WSR-88D that is capable of processing the polarimetric signals. The new RDA deployment is underway and is currently scheduled for completion of the U.S. network the week of September 25, 2006.

In 2020, the WSR-88D radars forming this NEXRAD network will be over 23 years old. In about the same time frame, most of the Nation's aircraft surveillance radars will be nearing the end of their design life. Decisions on replacing or repairing and upgrading these National radar assets must be made over the next 10 to 15 years. We are now on the threshold of a revolution in civilian radar capability, enabled by the adaptation of established military radar technology to existing civilian applications, plus new capabilities beyond what current systems can provide. Historically, civilian radars with large rotating antennas like the NEXRAD weather surveillance network and the aircraft surveillance radars used by the Federal Aviation Administration (FAA) evolved from military radar applications. During the past several decades, a new generation of military radars has matured. These electronically scanning phased array radars with no moving parts (rotating antennas) were originally developed to track multiple airborne objects such as aircraft and missiles simultaneously. The unique beam agility, increased resolution, and faster full-volume scan rate of phased array radar can enable a single radar unit to perform multiple weather and atmospheric surveillance tasks and, at the same time, track multiple airborne craft.

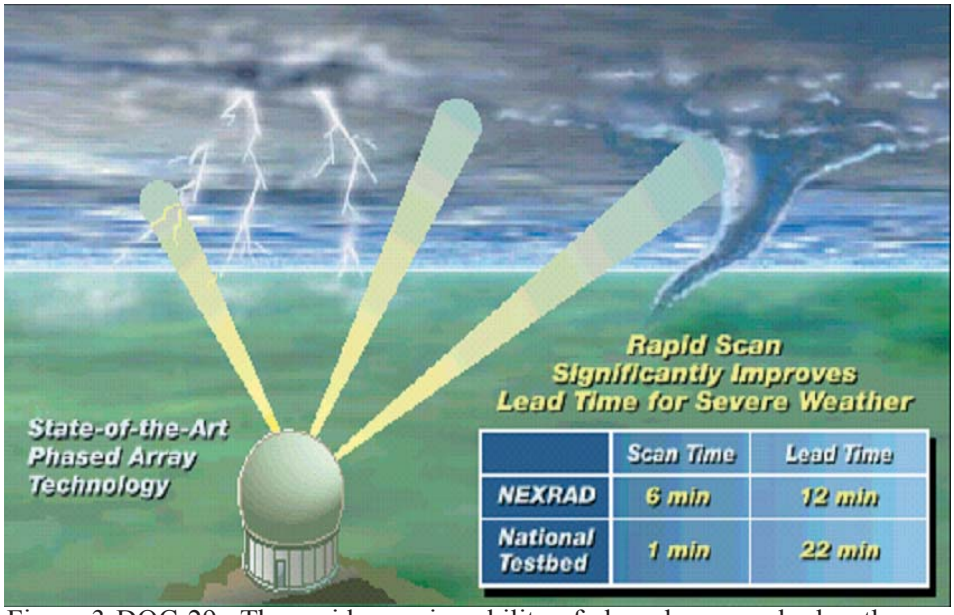


Figure 3-DOC-29. The rapid scanning ability of phased array radar has the potential to significantly increase the average lead times of tornado warnings.

Thus, a single network of multifunction phased array radar (MPAR) units could provide next-generation expansion of our current weather surveillance network, replace the Nation's aging air traffic surveillance radars, and meet homeland security and defense requirements for identifying and tracking non-cooperative craft operating over the U.S. homeland. MPAR will enable continued improvement of the Nation's severe weather warning system. It can provide adaptive sensing for warnings and nowcasts related to severe convective storms and the locally destructive effects of hurricanes (tropical cyclones) after they make landfall. Among the storm phenomena that could be tracked are tornadoes, strong wind gusts, hail, and locally heavy rains responsible for flash floods and mudslides. The enhanced weather surveillance provided by an MPAR network will provide economic benefits to domestic aviation and surface transportation systems. The agility and specificity of its multitasking beams will provide more detailed weather and atmospheric observations for urban meteorology, air quality nowcasts and forecasts, climate variability monitoring and forecasting, wildland fire monitoring and prediction, and atmospheric transport

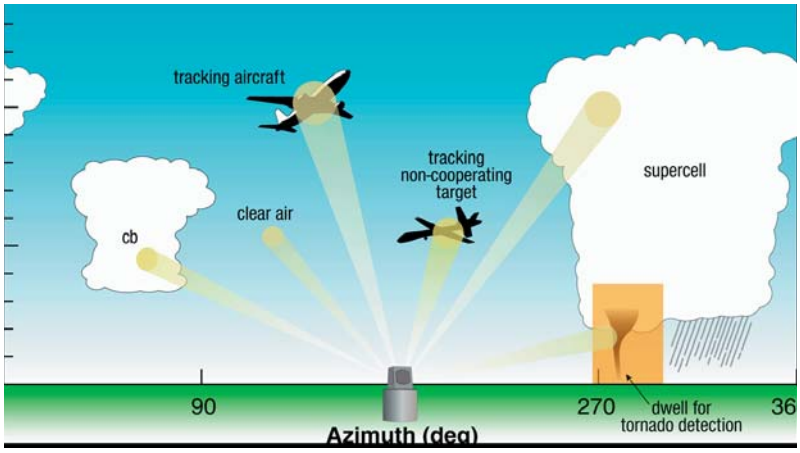


Figure 3-DOC-30. Electronically scanning phased array radars with no moving parts enable a single radar unit to perform multiple weather and atmospheric surveillance tasks and, at the same time, track multiple airborne craft.

and diffusion modeling. The non-cooperative aircraft surveillance capability of an MPAR network would complement the cooperative surveillance strategy planned for the Next Generation Air Traffic System (NGATS), while also addressing new craft tracking requirements of the Departments of Defense and Homeland Security. While research at NSSL is establishing the proof-of-principle for new applications of weather radar in these and other areas, the adaptive flexibility of MPAR will be essential in transferring these promising radar techniques to operations.

Because an MPAR network would replace multiple existing networks, it offers an affordable option to the alternative strategy of continuing with the existing civilian radar capability by repairing and eventually replacing aging units. Due to technology breakthroughs in radio frequency components, fueled by the wireless telephony and digital communications industries, the cost of a key MPAR component-the transmit-receive elements in an MPAR antenna-has dropped by orders of magnitude over the past 5 years, and this trend should continue. For a number of reasons, the operations and maintenance costs for MPAR units appear to be a third area of substantial savings relative to continuing to repair and replace current radar units as they age.

Thus, with respect to both capabilities and cost, MPAR is a promising option for meeting the Nation's future domestic radar surveillance needs. Using multiple beams and frequencies that are controlled electronically, NSSL has demonstrated phased array radar reduces the scan time of severe weather from six minutes for the NEXRAD radar to less than one minute, producing quicker updates of data and thereby potentially increasing the lead time for tornado warnings well beyond the current average of 13 minutes.

In support of improved understanding of the changing chemical composition of the atmosphere, the Field Research Division of the Air Resources Laboratory (ARL) has continued to refine its constant-level "smart" balloon. The smart balloon is intended to serve as a marker of parcels of air moving across the countryside and permitting samples to be made of the changes occurring in its composition. These balloons are being used both for air quality studies, such as the 2006 Texas study, and for hurricane research. The Field Research Division has also developed an Extreme Turbulence (ET) probe for measuring turbulence and surface fluxes in hurricanes. ET probes were successfully deployed into landfalling hurricanes in 2004, and plans are in place to eventually deploy them on moored NOAA buoys. The Oak Ridge Division of ARL continues to lead in the development of specialized sensors for measuring atmospheric turbulence. Their systems are now widely used for measuring the efficiency of coupling between the air and the surface, and have recently been selected for instrumenting the latest generation of research aircraft, manufactured in Italy.

In addition to the many weather related observing systems, OAR also dedicates significant time to improving the development, deployment, and monitoring of oceanographic related observing technologies and related data. As part of this effort, AOML manages the deployment of drifting buoys around the world, deploying some 300 new drifters annually and tracking nearly 700 as part of the Global Drifter Program. Using research ships, VOS, and U.S. Navy aircraft, Global Lagrangian Drifters (GLD) are placed in areas of interest. Once verified as operational, they are reported to AOML's Data Assembly Center (DAC). Incoming data from the drifter are then placed on the Global Telecommunications System (GTS) for distribution to meteorological services everywhere. The primary goal of this project is to assemble and provide uniform quality control of SST and surface velocity measurements. These measurements are obtained as part of an international program designed to make this data available in an effort to improve climate prediction. Climate prediction models require accurate estimates of SST to initialize their ocean component. Drifting buoys provide essential ground truth SST data for this purpose. The models also require validation by comparison with independent data sets. Surface velocity measurements are used for this validation.

In support of Global Climate Observing System (GCOS) requirements, OAR, in cooperation with NWS, the Office of Global Programs (OGP; housed within OAR), AOML,

and the Scripps Institution of Oceanography, maintains a network of approximately 100 meteorological drifting buoys in the Southern Hemisphere as part of the Southern Hemisphere Drifting Buoy Program. The buoys measure atmospheric pressure at sea-level, air temperature, surface sea water temperature, and surface currents. Observations are obtained through the ARGOS data collection and platform location system on-board the NOAA polar-orbiting satellites. The buoys are a subset of the Global Drifter Program.

The Tropical Atmosphere Ocean/TRIangle Trans-Ocean buoy Network (TAO/TRITON) array consists of approximately 70 Autonomous Temperature Line Acquisition System (ATLAS) and TRITON moorings in the tropical Pacific Ocean, telemetering oceanographic and meteorological data to shore in real-time via the ARGOS satellite system. Designed to improve detection, understanding, and prediction of El Niño, TAO/TRITON is a major component of the El Niño/Southern Oscillation (ENSO) Observing System, the Global Climate Observing System (GCOS), and the Global Ocean Observing System (GOOS). The array is supported primarily by the U.S. (NOAA) and Japan (JAMSTEC) with contributions from France (IRD) and Taiwan (NTU). The mooring array is maintained by the TAO Project Office located at the Pacific Marine Environmental Laboratory (PMEL) in Seattle, Washington. PMEL has responsibility for project management and logistics. The mooring array operations have recently been transferred to NWS. These buoys provide climate researchers, weather prediction centers, and scientists around the world with real-time data from the tropical Pacific. El Niño (the warm phase of the ENSO cycle) is associated with a disruption of the ocean-atmosphere system in the tropical Pacific and has important consequences for weather around the globe.

The Pilot Research Moored Array in the Tropical Atlantic (PIRATA) is a project designed as an extension of the TAO array into the Atlantic. The purpose of PIRATA is to study ocean-atmosphere interactions in the tropical Atlantic that are relevant to regional climate variability on seasonal, interannual and longer time scales. It consists of an array of 12 ATLAS moorings similar to those deployed in the Pacific. Planned expansion of the PIRATA array into the hurricane genesis region of the Atlantic will allow for a better understanding of ocean-atmosphere interactions on hurricane development and enhanced predictions of hurricane formation.

Figure 3-DOC-31. One of approximately 70 Autonomous Temperature Line Acquisition System (ATLAS) and TRITON moorings in the tropical Pacific Ocean.

In an effort to better understand and forecast climate, OAR has been deploying a global array of profiling floats since 2000. The broad-scale global array of temperature/salinity profiling floats, known as Argo, has already grown to be a major component of the ocean observing system with an intended deployment of 3000 floats. Argo floats are free-drifting profiling floats that spend most of their life "parked" at 1,000 or 2,000 meters depth in the ocean, regularly surfacing to make temperature and salinity profile measurements and providing those observations in real-time. As of August 2006, 2485 Argo floats have been deployed. The Argo array is part of the Global Climate Observing System/Global Ocean Observing System GCOS/ GOOS) and is a major contributor to the WCRP's Climate Variability and Predictability Experiment (CLIVAR) and the Global Ocean Data Assimilation Experiment (GODAE). Along with satellites, Argo provides a quantitative description of the changing state of the upper ocean and the patterns of ocean climate variability from months to decades, including heat and freshwater storage and transport.

As part of the backbone for the Integrated Ocean Observing System (IOOS), OAR supports the national ocean observation backbone through 29 deployed or planned operational ocean moorings as part of the Ocean Reference Station network. The operational ocean moorings provide measurements of high quality air-sea fluxes of heat, moisture, and momentum that will be used to make regional assessments of flux components from numerical weather prediction models and satellites. A partnership with the National Science Foundation's ORION program will greatly enhance the capacity of the network.

HIGH IMPACT WEATHER RESEARCH

In addition to research and development of observing systems and related technology, OAR also focuses on ways to improve our understanding and the predictability of severe weather systems and their associated hazards. Providing significant national leadership in this area, the National Severe Storms Laboratory (NSSL) focuses on research to better understand such hazards as tornadoes, hail, high winds, heavy rain and snow, lightning, and ice storms with the goal of helping the National Weather Service (NWS) improve forecasts and warnings. The parameters of storm development and intensification are identified and studied by incorporating observations from Doppler weather radar, satellites, remote-sensing wind profilers, instru-

mented aircraft, and lightning-location networks. NSSL's research includes assessment and improvement of numerical models to forecast severe weather systems.

NSSL provides significant technical and scientific support, with a focus on research and development, for the NWS WSR-88D radar program. In 2006, NSSL continued to develop techniques, in cooperation with the NWS, to forecast and warn of weather hazards to aviation and the general public.

NSSL's vision for the warning decision process continues to evolve as our scientists and engineers work toward integrating the next generation radar (MPAR) and storm-scale numerical models to create a storm-scale prediction capability for our National Weather Service partners. While it is not possible today, within the next decade we envision operational units using a "Warn on Forecast" methodology, e.g., a forecaster will use thunderstorm-resolving computer models for severe weather warnings in the same way as he/she does today with our current Doppler radar systems. It is believed that these enhancements to our operational weather capability will lead to a more accurate warning system which increases lead time and provides probabilistic information that enables the public to take the best reasonable action during a severe weather event.

During the spring and summer of 2006, NSSL conducted the Severe Hail Verification Experiment (SHAVE) with the goal of testing new technologies that will vastly improve the verification of severe weather events as well as the climate record of those events. SHAVE researchers documented hail swaths from severe thunderstorms at a high spatial and temporal resolution by integrating real-time meteorological data into Geographic Information Systems (GIS). This integration permitted the SHAVE team (NSSL/CIMMS scientists and University of Oklahoma students) to make verification phone calls to very specific locations. Rather than an average of 1-2 hail reports collected from each storm, SHAVE collected anywhere from 10-100 reports along the storm's paths at a much higher spatial resolution and with fewer time and space errors than in the official storm climate record (the Storm Data publication). Better verification data such as these are vital to future improvements to the warning process. These high-resolution data sets enable: (1) validation of new probabilistic warning techniques that would not otherwise be possible given the typically coarse spatial resolution of the severe event reports in Storm Data, (2) enhanced, independent verification of warnings issued by the National Weather Service, and (3) validation of high-spatial and temporal resolution hail detection tools.

Figure 3-DOC-32. Photo taken May 11, 1982, by NSSL storm intercept team in the hail core of a supercell thunderstorm that later produced an F2 tornado.

NSSL works with the Federal Aviation Administration's (FAA) Aviation Weather Research Program (AWRP) to develop weather radar applications that enhance the safety and efficiency of the aviation community and the National Airspace System. Work is focused on both convective weather and winter weather, with special attention to treating all WSR-88D radars within the continental U.S. as a single network. Such treatment allows NSSL to produce a single, authoritative 3-dimensional grid of radar data. Intensive research is also directed to polarimetric radar applications unique to aviation needs. Examples include winter time quantitative precipitation estimation, detection of icing conditions, and data quality issues unique to FAA users.

The NSSL is collaborating with the NWS Office of Hydrologic Development (OHD) and the Office of Climate Weather and Water Services in the development, testing, and research-to-operations of a 'state of the science' approach to quantitative precipitation estimation (QPE) and short-term precipitation forecasts (QPF). The goal of this cross agency collaboration is to increase warning lead times for the detection and prediction of flash floods and river flooding. This effort is part of the Advanced Hydrologic Prediction Services (AHPS), which is an essential component of the NWS Climate, Water, and Weather Services. The

research and development into QPE and QPF is being afforded by a Federal Aviation Administration and National Centers for Environmental Prediction collaboration towards the integration of radar networks into seamless high-resolution three-dimensional mosaics for use in aviation safety and atmospheric model data assimilation. NSSL has established the infrastructure and techniques for ingesting domestic and international weather surveillance radars, along with integrating satellite and surface observations, to facilitate research and development toward advance monitoring of the Nation's fresh water resources. The vision and objectives of the research is to improve the capability to effectively manage the Nation's fresh water resources and to mitigate the social and economic impacts of flooding through timely and accurate detection and prediction of precipitation.

NSSL continues to lead a project called CI-FLOW (Coastal-Inland Flood Observation and Warning) that uses NSSL's multi-sensor rainfall estimates to drive an NWS distributed hydrologic model that predicts streamflow to help NWS improve flash flood warnings. In addition, the streamflow information is used to drive three models run by our partners at N.C. State University, a water quality model, estuary model, and storm surge model. This system of coupled models, when fully integrated, can be used for land-use studies, algal bloom studies, pollution studies, inundation studies of landfalling tropical systems, for example.

NSSL is participating in NOAA's Hydrometeorological Testbed or HMT. The HMT is a NOAA-led research activity with several external partners (e.g., universities, water management groups, etc.). The objective of the overall HMT program, of which HMT-West is the first full-scale deployment, is to accelerate the infusion of new technologies, models, and scientific results from the research community into daily forecasting operations of the National Weather Service and its River Forecast Centers. The research activities in HMT-West this year focused on deployment of NSSL's SMART-R radar system to observe heavy rainfall events over the American River Basin near Sacramento, California. Twelve storm systems were observed and unprecedented data sets were collected in FY 2006.

NSSL has been working with U.S. Geological Survey (USGS) and NWS scientists to improve the debris flow warnings for Southern California. Recent fires in the foothills can lead to devastating debris flows (mudslides) when subsequent storms deposit relatively modest rains on those foothills. The USGS instrumented a recent burn area (the Harvard fire region near Burbank California) for high resolution studies in order to refine the warnings thresholds. NSSL contributed a mobile radar to make high-resolution radar estimates of precipitation over the Harvard burn area this last winter. Five rainstorms were observed, of which 2 produced moderate debris flows.

Improvement of short-range (1-12 hour) forecasting will be accomplished by the development and evaluation of new local data system technologies and techniques, many of which can be incorporated into operational weather forecasting in the near term. GSD develops and evaluates state-of-the-art workstations for forecast office environments. Specifically, GSD has and will continue to develop capabilities to allow the forecaster to integrate, view, and manipulate observations from current and planned meteorological sensing systems using computer-assisted data display and synthesis techniques. NSSL is collaborating with NWS and GSD to integrate some of NSSL's advanced single and multi-radar display capabilities into AWIPS.

GSD will continue efforts toward effective assimilation of diverse observational data into numerical prediction models. Data from the Aeronautical Radio Incorporated (ARINC) Aircraft Communications, Addressing, and Reporting System (ACARS); WSR-88D Doppler radars; and weather satellites, especially Geostationary Operational Environ-mental Satellite (GOES), are frequent and provide unprecedented resolution, either in the vertical or the horizontal, or both. These data are being more fully exploited in the Local Analysis and Prediction System which provides highly detailed analyses and forecasts over areas hundreds of kilometers on a side, and the Mesoscale Analysis and Prediction System, the basis for operational and frequent short-term forecasts for the lower 48 states. The system has been incorporated into the AWIPS system and is being used by a number of other agencies, not only for various regions of the U.S., but for a number of regions throughout the world.

OAR will continue to transfer knowledge of Doppler radar applications, severe weather systems, and heavy rainfall events; much of the transfer is through courses at the NWS training center. Visits and interactions with NWS centers, regional headquarters, and forecast offices continue and NSSL is participating directly in training programs, such as COMET in Boulder, Colorado, and the WSR-88D Operational Support Facility in Norman, Oklahoma.

A multi-year program of coastal meteorology research continues at the Pacific Marine Environmental Laboratory (PMEL). This program also involves ESRL and NSSL, the Seattle NWS Forecast Office, the National Center for Atmospheric Research (NCAR), and the University of Washington. Support for the program is also being provided by the Office of Naval Research. This research improves understanding of the effects of promi-

nent terrain on West Coast weather, with the ultimate goal of providing improved forecasts of coastal winds, precipitation, sea state, and storm surges. The emphasis is on the upstream effects of the coastal terrain in the storm environment when the background forcing is strong and the coastal forecasts are most critical. The approach involves special field observations and diagnostic studies using experimental numerical simulations. Field work featuring a NOAA WP-3 research aircraft in the 1990s, for example, has yielded meteorological data for the Pacific Northwest coast with low-level winds of up to 85 knots, in the vicinity of strong fronts and, in one case, an intense, landfalling low pressure system. The case studies from this work provide immediate insights on the influences of the coastal terrain on landfalling storms, and high quality data sets for numerical model initialization and validation. Follow-up field programs in FY 2004 and FY 2005 focused on cloud and precipitation processes using special observations from research aircraft and land-based radars. The results are providing information on how to improve forecasts of storms in the Western U.S.. This activity is also coordinated with the NWS Office of Hydrologic Development and NCEP's Climate Prediction Center for support to hydrologic resource forecasting to help better forecast floods and droughts.

MESOMETEOROLOGY AND PRECIPITATION FORECASTING AND WARNING RESEARCH

In support of NOAA's goal of protecting lives and property, OAR contributes to the development of techniques to improve short term forecasters of significant weather events. Through detailed case studies and regional climatologies, National Severe Storms Laboratory (NSSL) scientists have developed diagnostic tools and aids for operationally forecasting thunderstorms, lightning, flash floods, and large mesoscale convective storm complexes. Field programs were carried out and followed by extensive analyses were conducted to improve the science behind technology advances. Example programs whose data have been and continue to be analyzed include (1) the Severe Thunderstorm Electrification and Precipitation Study (STEPS) in 2000, (2) the International H2O Project (IHOP), (3) the Thunderstorm Electrification and Lightning Experiment (TELEX) 2003 and 2004, and (4) the annual collaborative severe storm research by NSSL, the NWS/SPC, and collaborators.

Other NSSL studies underway are focused on the precipitation structure of large storm systems (mesoscale convective systems), the interactions between meso-convective systems and the larger environment, the use of satellites to infer storm development and rainfall, short-range ensemble forecasting techniques, and winter storm forecasting procedures. Findings from these research activities lead to supporting the forecasting of a variety of high impact weather events.

NSSL will continue to investigate various model convective parameterization schemes, along with techniques to improve model initialization through four-dimensional data assimilation. Advances continue in numerical simulation and forecasting at mesoscale and stormscale resolutions. Current research is using data assimilation by ensemble Kalman Filter method, as well as lightning data assimilation, to improve forecasting of convection. At stormscale, pure simulation is also employed for improving understanding of dynamics, microphysics, and lightning. Toward the goal of improving operational mesoscale model and human forecasts of storms and their environments, NSSL researchers investigate the convection initiation (CI) process and the types of observations required to represent CI and storms in both research and operational mesoscale analysis and forecast model systems.

In 2002, NSSL contributed expertise and ground-based mobile radar, mobile mesonets, and mobile sounding observations during the International H2O Project (IHOP) conducted on the U.S. Southern Great Plains (SGP). The chief aim of the 2002 IHOP campaign is improved characterization of the four-dimensional (4-D) evolution of water vapor and boundary layer (BL) structure with application toward improving the prediction of convective storms. The SGP region is an optimal location due to existing experimental and operational facilities, strong variability in moisture, and active storms and convective systems providing most of the warm season precipitation east of the Rocky Mountains. Recent studies report a new method for objectively combining diverse radar and in-situ measurements to obtain internally consistent analyses of BL evolution and cloud formation with application to cases that illustrate the impact of drylines and cold fronts on the CI process. Given sound conceptual models of the CI process, forecasters in turn can interpret available observations more precisely to improve specificity and accuracy of storm forecasts. Another recent study reports the potential improvement of mesoscale model initialization via the assimilation of all types of real-time total and cloud-to-ground lightning observations to improve representation of ongoing convection and its integrated effects on model initial conditions.

NSSL has also made advances in interpreting lightning data in forecasting. This information will point to new ways for the National Weather Service to use lightning observations to improve forecasts and warnings of hazardous weather. NSSL operates state-of-the-science facilities that include the KOUN radar in Norman, which is a WSR-88D radar modified

with polarimetric parameters to provide information about the particle size and water phase of precipitation and the Oklahoma Lightning Mapping Array (LMA). The OK-LMA is a network of 11 stations in central Oklahoma that continuously maps in high space and time resolution the structure of all types of lightning in three-dimensions out to a range of 75 km and in two-dimensions out to a range of 200 km. All the technology advances and research findings are aimed at NSSL's contribution to advances in forecasting high-impact weather events.

NSSL is working with the NWS Storm Prediction Center (SPC) to improve the nation's ability to forecast severe weather and to enhance severe winter weather guidance products. Data collected during the IPEX campaign held in 2001 should help. The data are being analyzed by NSSL, SPC and University of Utah scientists. The IPEX field and research program was designed to improve the understanding, analysis, and prediction of precipitation and precipitation processes in complex terrain. Data analysis of IPEX continue in 2005. In addition, the SPC/NSSL collaboration has led to improvements in the way we understand convection initiated near the dryline and tornadoes spawned by hurricanes. A major forecast challenge for SPC forecasters is severe weather from elevated convection. Recent collaborative research shows the spatial and temporal distribution of such severe weather reports and begins to provide insight into processes that would improve our ability to forecast these events.

Figure 3-DOC-33. The OU Doppler-on-Wheels and the NSSL mobile laboratory take measurements of a snowstorm in Idaho during IPEX.

NSSL has developed a unique and vibrant collaboration with the operational forecasting community, which has recently been formalized with the establishment of the NOAA Hazardous Weather Testbed (HWT). The mutual interests of forecasters from the NOAA Storm Prediction Center, researchers from NSSL, and collocated joint research partners from the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) inspired the formation of the HWT. The testbed's activities have been varied, including activities such as daily map discussions involving imminent severe weather, loosely-related research projects involving 2-3 collaborators, and periodic intensive collaboration periods with larger groups. But the cornerstone of the testbed has been the SPC/NSSL Spring Program, a series of annual experiments that attracts 50-60 researchers and forecasters to Norman each year.

The premise of each Spring Experiment is to provide forecasters with a first-hand look at the latest research concepts and products, while immersing research scientists in the challenges, needs, and constraints of front-line forecasters. In practice, this program gives forecasters direct access to the latest research developments while imparting scientists with the knowledge to formulate research strategies that will have practical benefits. The end result is not only better severe-weather forecasts, but important contributions to the scientific literature as well. Science partners in recent Spring Experiments have included NCAR, NCEP/EMC, OU/CAPS, and numerous academic centers.

As the Norman meteorological community consolidates its diverse workforce in a common building, numerous groups are adopting the collaborative spirit and innovative approach of the HWT. At the same time, the HWT is expanding to embrace these groups and provide the framework for development and implementation of new technologies in different areas, particularly those focusing on shorter-timescale forecasting challenges. For example, NSSL's Severe Weather Warning Applications and Technology Transfer (SWAT) team and the NWS Norman WFO are stepping into important leadership roles within the HWT.

NSSL anticipates that the proof of concept established through the annual NSSL/SPC Spring Experiment and the early years of the HWT will play an important role in bringing together the diverse elements of the Norman meteorological community and like-minded meteorologists from across the country. In fact, Congress recently provided seed funding to help foster a collaboration between the HWT, the University of Alabama at Huntsville, and NASA's Short-term Prediction Research and Transition Center (SPoRT), a joint center staffed by NASA research meteorologists also located in Huntsville, and the Huntsville WFO. The group in Oklahoma is being referred to as HWT/Norman and the groups in Alabama are being referred to as HWT/Huntsville. The HWT/Norman has decades of experience on severe weather and tornadoes characteristic of the central plains (long-lived supercell thunderstorms, for example), while the HWT/Huntsville has experience with the severe weather and tornadoes that are characteristic of the southeast U.S. (especially those spawned by land-falling tropical systems). Working together, we believe these groups will strengthen the nation's collective knowledge and understanding of these hazardous convective events, leading to significant contributions to the science and improved severe-thunderstorm and tornado watches and warnings for the public.

NSSL has been on the forefront of short-range ensemble forecasting and exploring the use of ensembles for forecasts of severe weather. During the summers of 2002 through 2004, NSSL was a partner in the New England High-Resolution Temperature Program. The role of NSSL was to provide several model forecasts and collect forecast data from NCEP and FSL and develop post-processing techniques to improve upon Model Output Statistics. A simple yet powerful bias correction approach was developed in which the past 12 days of model data and observations are used to bias correct today's forecasts. Results indicate that the bias-corrected ensemble forecasts improve upon MOS and also provide reliable probabilistic forecast information. In addition, a novel approach to providing reliable probabilistic quantitative precipitation forecasts was developed and tested. In 2003, NSSL in partnership with the SPC embarked on an experiment to test the value of human forecasters in creating ensemble initial condition perturbations. Results indicate that human-generated ensemble perturbations can contribute positively to ensemble skill for severe weather events, indicating that the knowledge and experience of forecasters needs to be put to better use as we learn how to design ensembles for a variety of end users. With ensembles a regular part of the NCEP operational suite, approaches such as bias correction and human-generated ensemble perturbations as crucial to making best use of the model forecast data for both routine and severe weather forecasts.

Mesoscale dynamics research at the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey, develops and utilizes atmospheric models with limited spatial domains to understand mesoscale phenomena and the interaction of these regional scale features with the atmosphere's larger-scale synoptic processes. As part of these research activities, GFDL scientists investigate the practical limits of forecast models to predict the behavior of these mesoscale features through model sensitivity studies. (Figure 3-DOC-20). Current research focuses on extending these activities to the global domain through state-of-the-art global atmospheric models.

In 1994, the Global Systems Division (GSD) of ESRL implemented a Rapid Update Cycle (RUC) model at the NWS National Centers for Environmental Prediction (NCEP) and continues to provide periodic follow up upgrades. The RUC provides a new analysis of surface and atmospheric conditions every three hours as well as short-range predictions for the next 12 hours. This information is useful to forecasters at local NWS offices around the country and also supports commercial and general aviation.

A higher-resolution, higher-frequency version of the RUC was implemented at NCEP in 2005. The 13-km version of NOAA's Rapid Update Cycle (RUC13) model became operational at 1200 UTC Tuesday 28 June 2005, at the National Centers for Environmental Prediction (NCEP). This is a major milestone for improving the RUC high-frequency short-range forecasts for NOAA and external users, especially for aviation and severe weather forecasting. The main changes include higher horizontal resolution (from 20 km to 13 km), improved data assimilation especially for moisture/cloud fields, and improved cloud/precipitation physics. Most notable improvements are in surface and cloud/precipitation forecasts, resulting in part from assimilation of new observation types in the RUC13. The model updates every hour, incorporating information from virtually all high frequency data sources: hourly wind profiles; WSR-88D (Doppler radar) velocity azimuth displays; ACARS reports (up to 65,000 per day); cloud-drift winds and estimates of total precipitable water vapor from the GOES satellites; and surface obser-

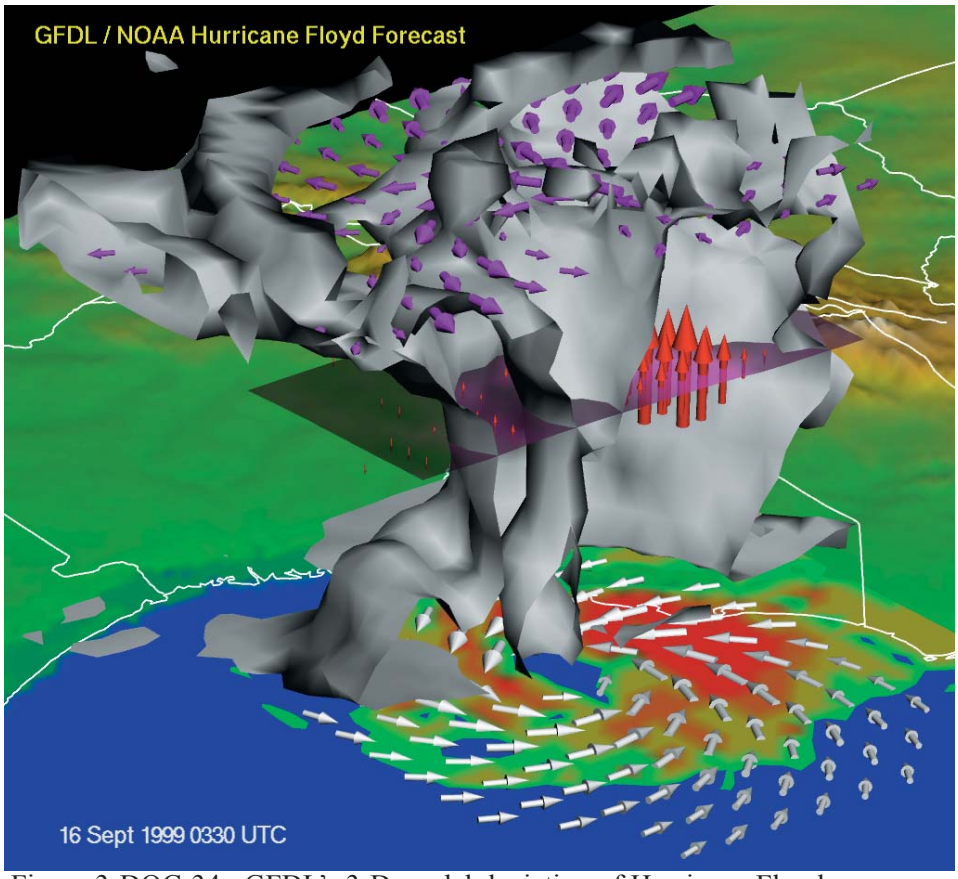


Figure 3-DOC-34. GFDL's 3-D model depiction of Hurricane Floyd.

vations. The new RUC also includes explicit forecasts of cloud droplets, ice crystals, raindrops, snowflakes, and graupel (snow pellets). This improves forecasts of precipitation type. The RUC exploits a new, multi-level soil and vegetation model to improve forecasts at and near the earth's surface.

Along with NCAR, NCEP, and the university community, GSD is collaborating on the development of a new mesoscale model, the Weather Research and Forecast (WRF) model. The goal is to have the WRF model become a community model and a tool both for experimental and operational prediction, thus paving the way for quick realization of research advances in forecast dissemination to the public and industry.

The Air Resources Laboratory (ARL) is also involved in the development of new models for operational use by NCEP. The main focus is on mesoscale models and in the development of new capabilities for data assimilation. In particular, the new generation of mesoscale models (such as the WRF model referred to above) will require advanced descriptions of the coupling between the air and the surface, a matter that is being studied intensively in ARL programs involving closely interacting measurement and modeling activities. To this end, ARL continues to work closely with the Chemical Sciences Division (CSD) of ESRL to maintain the nation's surface radiation network (SURFRAD), data from which are now routinely employed to test both forecast mesoscale models (such as the Eta model) and satellite outputs. ARL conducts research on the surface energy balance and on the spatial variability of surface fluxes using aircraft. In addition, ARL serves as the provider of the NCEP modeling capability to address situations of atmospheric dispersion, such as of emissions from sources like volcanos, industrial enterprises, and nuclear accidents. In recent work, ARL is adapting a new system developed to forecast dispersion of smoke from forest fires, in a study performed in collaboration with the Association of South East Asian Nations, the U.S. Forest Service, and The Mediterranean Centre for Environmental Studies Foundation. The present program will provide interim products to the joint NOAA-EPA Air Quality Forecasting Program to improve smoke dispersion estimates in the particulate forecast model.

TROPICAL ATMOSPHERIC RESEARCH

The Tropical Dynamics and Climate Program of the ESRL Physical Sciences Division (PSD) is using precipitation profilers to study the structure, evolution and variability of precipitating cloud systems in the tropics and elsewhere. Precipitation measurements can be made with sufficient vertical resolution to categorize precipitation in deep and shallow convective systems and in stratiform conditions. A recent focus of research with profilers has been to provide ground validation research in support of satellite precipitation measurement missions such as the NASA Tropical Rainfall Measuring Mission (TRMM). These observations have provided important information on the vertical structure and temporal evolution of precipitating cloud systems during TRMM Ground Validation field campaigns. The observations made during the field campaigns are the subject of collaborative research with other TRMM researchers with an emphasis on the use of profilers to calibrate scanning radars used for TRMM ground validation research and the use of profilers to retrieve drop-size distributions and related precipitation parameters of interest to the TRMM Science Team. Validation of drop-size distributions used in algorithms is key to improving the retrieval of rainfall estimates from the TRMM satellite data. The profiler-based precipitation research described above also can be used to provide calibration of NEXRAD scanning radars as has recently been demonstrated for Melbourne, Florida. In related activities PSD is carrying out hydrometeorological studies in collaboration with the NWS in demonstrating the value of hydrometeorological testbeds as a means of improving the transition of scientific advances to operations.

HURRICANE ANALYSIS AND PREDICTION RESEARCH

The Atlantic Oceanographic and Meteorological Laboratory's Hurricane Research Division (HRD) mission is to advance the understanding and prediction of hurricanes and other tropical weather. HRD's research is based on a combination of models, theories, and observations, with particular emphasis on data obtained with research aircraft. The goals of this research are to:

- Advance the prediction of tropical cyclone intensity change by improving understanding of the processes that modulate internal storm dynamics and storm interactions with the atmosphere and ocean;
- Improve the prediction of tropical cyclone tracks by enhancing understanding of the interactions between a tropical cyclone and its environment through an optimal analysis of field observations;
- Improve the understanding of and ability to predict tropical cyclone frequency and intensity on intraseasonal, interannual, decadal and longer time scales; and
- Enhance the ability to diagnose and predict the impact of tropical cyclones on life and property through wind, rain, waves, and storm surge.

These goals are accomplished by:

- Designing and conducting research experiments in the hurricane to collect and provide data for research and applications;
- Analyzing these data sets and publishing the research in the refereed lit-

erature;

• Developing new technology and applications based on this research to improve NOAA's products; and

• Providing outreach to the public through the WWW, conferences, presentations, and other means.

Much of HRD's research is based on the in-situ and remotely-sensed observations in the inner core of tropical cyclones and their surrounding environment. These observations are primarily collected in our annual field program using the two NOAA turboprop aircraft and jet operated by the NOAA Aircraft Operations Center (AOC). The field program is used to carry out scientific experiments designed to address the goals stated above. Data sets gathered by these experiments, combined with dynamical and statistical models and theoretical development, range from global to microscale, forming the cornerstone of research in HRD. Because of this extensive field experience, HRD scientists are recognized internationally for their knowledge of tropical cyclones as well as their expertise in technological areas such as airborne Doppler radar, dropsondes, cloud microphysics, and air-sea interaction, to name a few. These assets make HRD unique worldwide, and provide NOAA a unique capability.

In 2005, NOAA's HRD began a multi-year experiment called the Intensity Forecasting Experiment (IFEX). Developed in partnership with NOAA's Environmental Modeling Center (EMC), National Hurricane Center (NHC), Aircraft Operations Center (AOC), and National Environmental Satellite Data Information Service (NESDIS), IFEX is intended to improve the prediction of hurricane intensity change by:

1. collecting observations that span the tropical cyclone lifecycle in a variety of environments;
2. developing and refining measurement technologies that provide improved real-time monitoring of tropical cyclone intensity, structure, and environment; and
3. improving our understanding and prediction of the physical processes important in intensity change for a tropical cyclone at all stages of its lifecycle.

Observations are collected in a variety of tropical cyclones at different stages in their lifecycle, from formation and early organization to peak intensity and subsequent landfall, decay over open water, or extratropical transition. These observations also aid in the improvement of operational models and the development of the next-generation operational hurricane model, the Hurricane Weather Research and Forecasting (HWRF) model system. There are several unique aspects of IFEX in 2006, that will help improve our understanding and prediction of hurricane intensity change. Some examples are provided below:

• Hurricane genesis experiment - Take data to improve our knowledge of the evolution of tropical waves to tropical storms.

• Impact of Saharan air on intensity forecast models - Recent research has shown that very dry air originating from the African continent, called the Saharan Air Layer (SAL), may be an important factor in hurricane intensity change.

• Doppler Radar - Mapping of the center wind field from airborne tail Doppler radar and its transmission to EMC and NHC in real-time.

• The 2006 international African Monsoon Multidisciplinary Analysis (AMMA) and NASA AMMA (NAMMA) field campaigns are concurrent research efforts that will compliment NOAA's IFEX research goal to observe and describe intensity change in storms developing off the African coast. Much of NOAA's tropical cyclone research will be coordinated with AMMA and NAMMA in 2006 with a focus on investigating the SAL, and how it interacts with developing hurricanes.

HRD coordinates its programs with other NOAA organizations, e.g., AOC, NESDIS, and NCEP, in particular with EMC and NHC. HRD maintains active research programs with, and receives funding from other governmental agencies, in particular, the Department of the Navy's Office of Naval Research (ONR) and the National Aeronautics and Space Agency (NASA).

In program areas where it is beneficial to NOAA, HRD arranges cooperative programs with scientists at the National Center for Atmospheric Research, and at a number of universities. For example in 2004, HRD part-

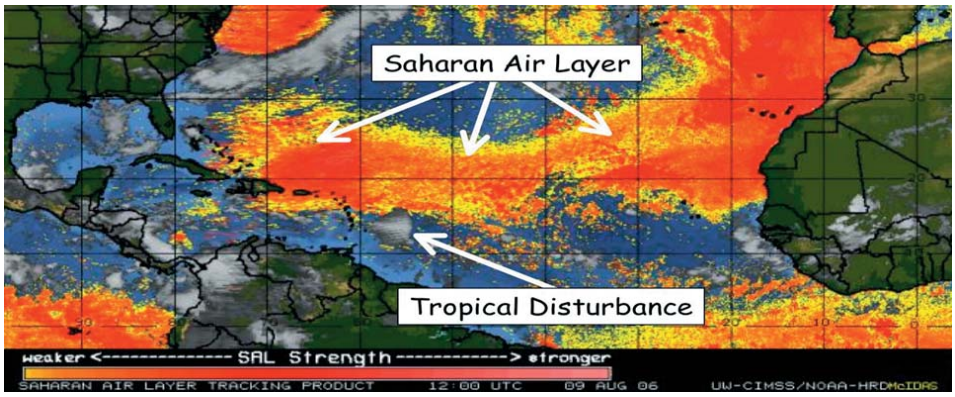


Figure 3-DOC-35. This August 9, 2006 infrared satellite image from NOAA's GOES satellite shows a Saharan Air Layer (SAL) outbreak (yellow to red shading) spanning nearly 4,000 miles across the North Atlantic. A tropical disturbance is indicated along the southern periphery of the SAL and was likely being suppressed by the SAL's dry dusty air and strong mid-level winds.

nered with ONR-sponsored university and Federal scientists on the Coordinated Boundary Layer Air-Sea Transfer (CBLAST) experiment focused on improving numerical model parameterization of the air-sea transfer of energy that fuels the storms. HRD also integrated two recent NASA Convective and Moisture Experiments (CAMEX-3, 4) in 1998, 2001. Finally, in 2005, HRD partnered with the NASA-sponsored Tropical Cloud Systems and Processes (TCSP) experiment and the NSF-sponsored Hurricane Rainband and Intensity Change Experiment (RAINEX) to compliment NOAA's IFEX research goals.

Under the USWRP and its participating agencies, OAR, NWS, and the National Environmental Satellite Data Information Service (NESDIS) established a Joint Hurricane Testbed (JHT) at the Tropical Prediction Center in Miami, Florida, in 1999 (http://www.nhc.noaa.gov/jht/index.shtml). This testbed is where the hurricane research is evaluated for operational use and those research products passing the test will be handed off to operations.

NUMERICAL ANALYSIS AND PREDICTION MODELING

As part of its weather research activities, GFDL conducts long lead-time research to understand the predictability of weather on both large and small scales and to translate this understanding into improved numerical weather prediction models. Three groups at GFDL are engaged in weather research activities: Climate Dynamics and Prediction, Weather and Atmospheric Dynamics, and Atmospheric Physics and Chemistry.

The Goal of the Climate Dynamics and Prediction Group is to develop and use computer models of the atmosphere-ocean- ice-land system in order to:

- Identify and elucidate the physical and dynamical mechanisms which maintain climate and cause its variations on seasonal to centennial time scales;
- Assess and understand the predictability of the climate system on seasonal and longer time scales, including the El Niño phenomenon; and
- Evaluate the impact of human activity on the Earth's climate system

This group is charged with studying and modeling climate phenomena on seasonal to multi-century time scales. The group's work is highly relevant to key elements of the NOAA Strategic Vision, especially Mission Goal 2 to "Understand climate variability and change to enhance society's ability to respond". In addition to examining a wide range of climate time scales, various members of the group have expertise spanning the expansive set of complex and interconnected parts that together constitute the Earth's physical climate system (this includes the atmosphere, ocean, land surface and sea ice). Group members participate in the development, testing, application, and analysis of numerical models of the climate system. Running on supercomputers, these models are the research tools used by group members to both advance our understanding of the Earth's climate system and to generate products relevant to assessment and policy decision support.

The Weather and Atmospheric Dynamics Group at GFDL improves our understanding of atmospheric circulations ranging in scale from hurricanes to extratropical storms and the general circulation, with an emphasis on extreme weather events and the interplay between weather phenomena and climate variability and change, using high resolution atmospheric modeling as the central tool. This effort is augmented by the Atmospheric Physics and Chemistry group, which performs research to improve our understanding of the interactive three-dimensional radiative-dynamical-chemical-hydrological structure of the climate system from the surface and troposphere to the upper stratosphere and mesosphere on various time and space scales. This is achieved by employing meteorological observations in conjunction with models for diagnostic analyses of atmospheric processes, and evaluating and improving parameterizations employed in weather and climate models; modeling the interactions between clouds, convection, radiation and large-scale dynamics to understand their roles in climate and climate change; and modeling the physics, chemistry and transport of atmospheric trace gases and aerosols to investigate the impact of future emissions on regional and global air quality, and to investigate the regional and global climatic effects due to changes in natural and anthropogenic radiatively-active species.

AIR QUALITY RESEARCH

The principal mission of the Air Resources Laboratory (ARL) is to improve the capability to forecast changes in air quality and atmospheric deposition. Deposition is the factor that links the pollutant characteristics of the air with the terrestrial and aquatic environments. ARL's research focuses on the lower atmosphere, where the atmosphere is in direct contact with other media-- aquatic, terrestrial, and biospheric. The core of ARL research relates to studies of the atmosphere as a component of the total environment. Much of this work is in collaboration with other parts of NOAA (principally NCEP) and with other agencies, such as EPA, DOE, and the DoD.

The ARL Headquarters Division in Silver Spring, Maryland, develops models for air quality prediction, for use in special forecasting (both weather and air quality) programs, and in emergency response. The Atmospheric Sciences Modeling Division, in Research Triangle Park, North Car-

olina, develops predictive models on local, regional, and global scales for assessing changes in air quality and air pollution exposure as affected by ecosystem management and regulations. This work is primarily to provide technical guidance to the EPA on air pollution control strategies for attainment and maintenance of ambient air quality standards, and for the provision of ozone and particulate matter forecasts in support of the joint NOAA-EPA Air Quality Forecasting program.

The ARL Atmospheric Turbulence and Diffusion Division, in Oak Ridge, Tennessee, conducts studies to improve understanding of atmospheric transport, diffusion, and air-surface exchange processes, and to develop new predictive models.

The ARL Field Research Division, in Idaho Falls, Idaho, designs and conducts field studies to evaluate the performance of transport and dispersion models, over local, regional, and continental scales. The ARL Special Operations and Research Division (SORD) in Las Vegas, Nevada conducts research on problems of mutual interest to NOAA and DOE that relate to the Nevada Test Site, its atmospheric environment, and its emergency preparedness and emergency response activities. SORD also serves as the main NOAA facility working with the Cooperative Institute for Atmospheric Studies and Terrestrial Applications (CIASTA) of the University of Nevada system.

ARL participates in two national networks that direct research attention on the needs of the next generation of predictive models. The Atmospheric Integrated Research Monitoring Network (AIRMoN) is a nested-network with sites of varying complexity addressing evolving scientific issues of wet and dry deposition from the atmosphere. A major current item for scientific attention is the atmospheric deposition of nitrogen compounds and its role in promoting eutrophication of ecosystems, primarily coastal. The ARL-developed Integrated Surface Irradiance Study (ISIS) serves as the national array of monitoring stations for solar radiation (and ultraviolet-B) with a subset of more advanced stations (the SURFRAD array) where both incoming and outgoing radiation components are monitored. Many of the SURFRAD stations are augmented with instrumentation to measure fluxes of sensible heat, latent heat, momentum, and carbon dioxide. Thus, the SURFRAD program is evolving into one of complete energy balance with supporting data on carbon dioxide exchange. ISIS and SURFRAD are presently operated by Chemical Sciences Division (CSD) of ESRL. This work forms an intersection with the new flux measurement networks in the U.S. and overseas, referred to as "Ameriflux" and "Fluxnet." All of this work is coupled with ARL research on atmospheric aerosols and with the development of new automatic methods for measuring cloud cover.

Much of ARL's research focus is on expressing air surface exchange processes in numerical models. To this end, ARL scientists have been instrumental in developing methods for describing an air surface exchange appropriate for use with model grid cells of several tens of kilometers on a side. To test the aerial integration capabilities, ARL has instrumented an aircraft of the NOAA fleet (a DeHavilland Twin Otter) to measure all of the eddy fluxes as well as a number of trace gas exchange rates. This instrumented aircraft has been used in several field experiments and has already demonstrated that considerable error can result when local values are inappropriately taken to represent larger areas.

ARL also provides forecast support to NOAA's emergency response systems with emphasis on chemical, nuclear, and volcanic events. For this application, ARL develops and couples advanced dispersion models with the forecast products of the NWS to provide a basis for trajectory and dispersion calculations. The models in question are now widely accepted. The Hazardous Atmospheric Release Model (HARM) is operationally employed at a number of DOE locations. The ARL Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model is now operational in many countries, including China and Australia, as the national dispersion forecasting capability. It also serves the NWS in this role. Registered users can also access HYSPLIT products via the Internet. HYSPLIT is the major product employed in the operations of the Regional Specialized Meteorology Center (RSMC) set up as a joint undertaking of ARL and NCEP under the auspices of the World Meteorological Organization (WMO). The WMO/ RSMC is the source of dispersion products in the event that a pollution plume (in this case, radioactive) crosses international boundaries.

The provision of dispersion forecasts by ARL scientists extends to two specific areas of special relevance - the Nevada Test Site and the Idaho National Laboratory. ARL maintains staffs of dedicated dispersion meteorologists at each location, where site-specific models are developed and run using data generated by dedicated regional networks of meteorological sensors. These sites also serve as research testbeds for improving ARL's dispersion models, such as the HYSPLIT model.

Each of ARL's divisions also partici-

pates in a cooperative agreement designed to explore the synergy that can be accomplished by collaboration between the government and private industry. The focus is the use of private sector data to address homeland security threats and potential local accidental events, as well as protection of the general population through the provision of better data in response to weather and climate related events. The intent of the program is to address threats where most of the population lives - in cities - exploring the use of the large non-government database that is available to most cities for use in the next generation of computer models.

The Chemical Sciences Division (CSD) of ESRL coordinates the Health of the Atmosphere air quality research effort. NOAA's Health of the Atmosphere research is focused on the atmospheric science that underlies regional and continental air quality, with the goal of improving our ability to predict and monitor future changes, leading to improved scientific input to decision-making. CSD, ARL, GMD, GSD, PMEL, and PSD participate in the research. The Health of the Atmosphere research goals are:

• Characterize regional ozone episodes: Characterize the factors that cause poor air quality in regions of the U.S. where excessive levels of ground-level ozone and fine particle pollution are occurring. In the summers of 2002 and 2004, two major field investigations were carried out to characterize air quality in the New England region. Ground-based measurements, ship and aircraft measurements, forecasting, and modeling analyses were applied in the research. Among the processes investigated were the role of nighttime chemistry in the formation of ozone pollution, the role of the sea-breeze/land-breeze circuit in influencing New England's air quality, and the role of the marine boundary layer as a conduit for the movement of pollutants throughout the region.

• Document trends in air quality: Help evaluate predicted atmospheric responses to changes in emissions (i.e., the ongoing measurements provided by the Atmospheric Investigation, Regional Modeling, Analysis and Prediction (AIRMoN) and the ozone profiling networks).

• Develop a better understanding of the fundamental science underlying the processes responsible for the formation and distribution of fine particles in the atmosphere to improve the atmospheric predictive capability that links sources of fine particles and their precursors to human exposure and visibility impairment.

Under the future Health of the Atmosphere research umbrella, the OAR Laboratories integrate their meteorological, chemical, and forecasting expertise to support an assessment and prediction capability for regional air quality that incorporates the influence of multiple-timescale meteorology/climatology. While the ambient levels of pollutants like ozone and fine particles are clearly dependent on pollutant emissions, the variation in those levels is also driven by meteorology, both in the short term and longer term. Therefore, assessing both the intended long-term improvements in air quality and the more-episodic variations requires an understanding, not only the atmospheric linkages between emissions and concentrations, but also in understanding the coupled chemical and meteorological processes. Research efforts will also focus on an evaluation and improvement of the tools used to forecast future air quality and the observing systems needed to evaluate their skill.

This approach was used in the summer 2004 New England Air Quality Study (NEAQS), which built on the groundwork laid by the scoping study done as NEAQS 2002. In 2004, NEAQS was conducted in cooperation with other agencies' complementary field studies as the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT). Observations were made from an array of platforms that includes a dozen aircraft, the NOAA research vessel Ronald H. Brown, and several ground sites in New England, Canada and Europe. NEAQS will help provide the scientific understanding required to underpin the region's future efforts to improve air quality for its citizens and required to develop advanced air quality forecast capabilities.

NOAA is leading a similar effort in East Texas during the Summer/Fall of 2006. Two NOAA aircraft and the research vessel Ronald H. Brown are being deployed to East Texas and the Gulf of Mexico in a joint air quality-climate study. NOAA is working with the local air-regulatory agency, the Texas Commission on Environmental Quality (TCEQ), university researchers, and scientists from sister Federal agencies (NASA, EPA and DOE) to better understand the causes of, and potential solutions for, poor air quality in the region. The extensive data set collected will also be employed to evaluate and improve air quality forecast models.

Figure 3-DOC-36. The research vessel, Ronald H. Brown.

The Air Quality Research Subcommittee (AQRS) of the Committee on Environment and Natural Resources (CENR) provides interagency collaboration at the U.S. Federal level. NOAA co-leads the AQRS. On the broader international arena, the coordi-

nating body is the North American Research Strategy for Tropospheric Ozone (NARSTO), a tri-lateral public/private partnership focused on ozone and particulate matter research in the U.S., Canada, and Mexico.

PSD and CSD use their suite of remote sensors, including a mobile profiler network, airborne and ground-based ozone Lidars, Doppler Lidar, and supporting turbulence instrumentation to understand and better model the transport, transformation, and fate of primary and secondary pollutants in both rural and urban environments as well as in complex orography. PSD and CSD participated in field programs in FY 2002 designed to develop a deeper understanding of climate variability and source pollutants in the New England region, and to investigate the composition of air masses along the Pacific coast of North America as part of the Intercontinental Transport and Chemical Transformation (ITCT) program. ITCT is a coordinated international research program designed to address the question, "How does the transport of chemicals from one continent influence the air quality in other continents, as well as regional and global climate?" PSD and CSD will be deploying a number of lidar systems and wind profiler radars in support of these programs. In 2005, GMD added high resolution ozone profile measurements to seven light aircraft instrument packages that are flown on weekly/bi-weekly greenhouse gas sampling profiles across the continental U.S. Within two years ozone instruments will be added to an additional 14 profiling aircraft. This data will be evaluated for possible integration into air quality and ozone forecast models.

The National Ocean Service (NOS) monitors, assesses, and forecasts conditions in the coastal and oceanic environment to maintain a healthy, safe, and economically productive coastal and oceanic environment for present and future generations. NOS is the primary civil agency within the Federal government responsible for the health and safety of our nation's coastal and oceanic environment. Largely through the Tides and Current Program line, NOS acquires water levels, currents, winds, and other physical oceanographic and meteorological data, and distributes these data and circulation predictions as elements of an integrated NOS program to provide a comprehensive science-based suite of information products required by the marine transportation community to ensure safe and efficient marine transportation, including the transport of oil and other hazardous materials. NOS also provides coastal oceanographic and meteorological products required by the National Weather Service (NWS) to meet its short-term weather and forecasting responsibilities, including tsunami and storm surge warnings. NOS manages several observing systems and programs, however four in particular are heavily linked to the capability of NOAA to meet weather and water needs of the nation.

NATIONAL WATER LEVEL OBSERVATION NETWORK (NWLON)

NOS manages the NWLON, 200 stations located along the coasts of the U.S. and the Great Lakes, from which water level data, as well as other oceanographic and meteorological data, are collected and disseminated. NWLON provides a number of NOAA and other Federal programs with data and supporting information, such as the NOAA Nautical Charting Program, NWS Tsunami Warning System, NWS storm surge warning/forecast activities, and the Climate and Global Change Program. An event triggered or manually triggered NWLON modification is now operational that allows emergency "Tsunami Warning" GOES transmissions to NWS when the water level exceeds a specified high/low limit or when the rate of change between the standard 6-minute water level values exceeds a specified value. A similar event triggered modification is also operated for the NWS storm surge warning program when expected elevations are predicted or observed during coastal storms and hurricanes.

This capability for high-rate data has recently been enhanced at many stations by the introduction of 6-minute interval GOES transmissions. Although not all NWLON stations are presently equipped with meteorological sensors, an increasing number of stations are each year. Water level and meteorological data are automatically formatted into bulletin format for inclusion into the NOAA AWIPS pipeline.

PHYSICAL OCEANOGRAPHIC REAL-TIME SYSTEM (PORTS®)

PORTS® is a decision support tool which improves the safety and efficiency of maritime commerce and coastal resource management through the integration of real-time environmental observations, forecasts, and other geospatial information. PORTS® measures and disseminates observations and predictions of water levels, currents, salinity, and many meteorological parameters, e.g. winds, barometric pressure, and visibility, needed and requested by the mariner to navigate safely. Highway and railroad bridge mounted "Air Gap" sensors for water level detection are presently being developed and are included in future plans for PORTS®.

The 13 existing PORTS® systems come in a variety of sizes and configurations, each specifically designed to meet local user requirements. PORTS® are partnership programs in which local operating partners fund the installation and operation of the measurement systems. The largest of NOS's existing installations is comprised of over 26 separate instruments. The smallest consists of a single water level gauge and associated oceanographic and meteorological instruments, i.e. winds, barometric pressure, etc. (Figure 3-DOC-37).

Regardless of its size, each PORTS® installation provides information that allows shippers and port operators to maximize port throughput while maintaining an adequate margin of safety for the increasingly large vessels visiting U.S. ports. In addition, prevention of maritime accidents is the most cost effective measure that can be taken to protect fragile coastal ecosystems. One major oil spill, e.g. EXXON VALDEZ, can cost billions of dollars and destroy sensitive marine habitats critical to supporting coastal marine ecosystems. PORTS® provides information to make navigation safer, thus reducing the likelihood of a maritime accident, and also provides the information necessary to mitigate the damages from a spill, should one occur. An extensible PORTS® can be integrated with other marine transportation technologies such as Electronic Chart Display Information Systems (ECDIS) and Vessel Traffic Systems (VTS).

NATIONAL OPERATIONAL COASTAL MODELING PROGRAM (NOCMP)

NOCMP serves a variety of users with oceanographic nowcast forecast products for ports, estuaries and the Great lakes. The integration of PORTS® technology and numerical circulation models allows nowcasts and predictions of parameters within the boundaries of the models even at locations where physical measurements are not available. The Chesapeake Bay Oceanographic Forecasting System

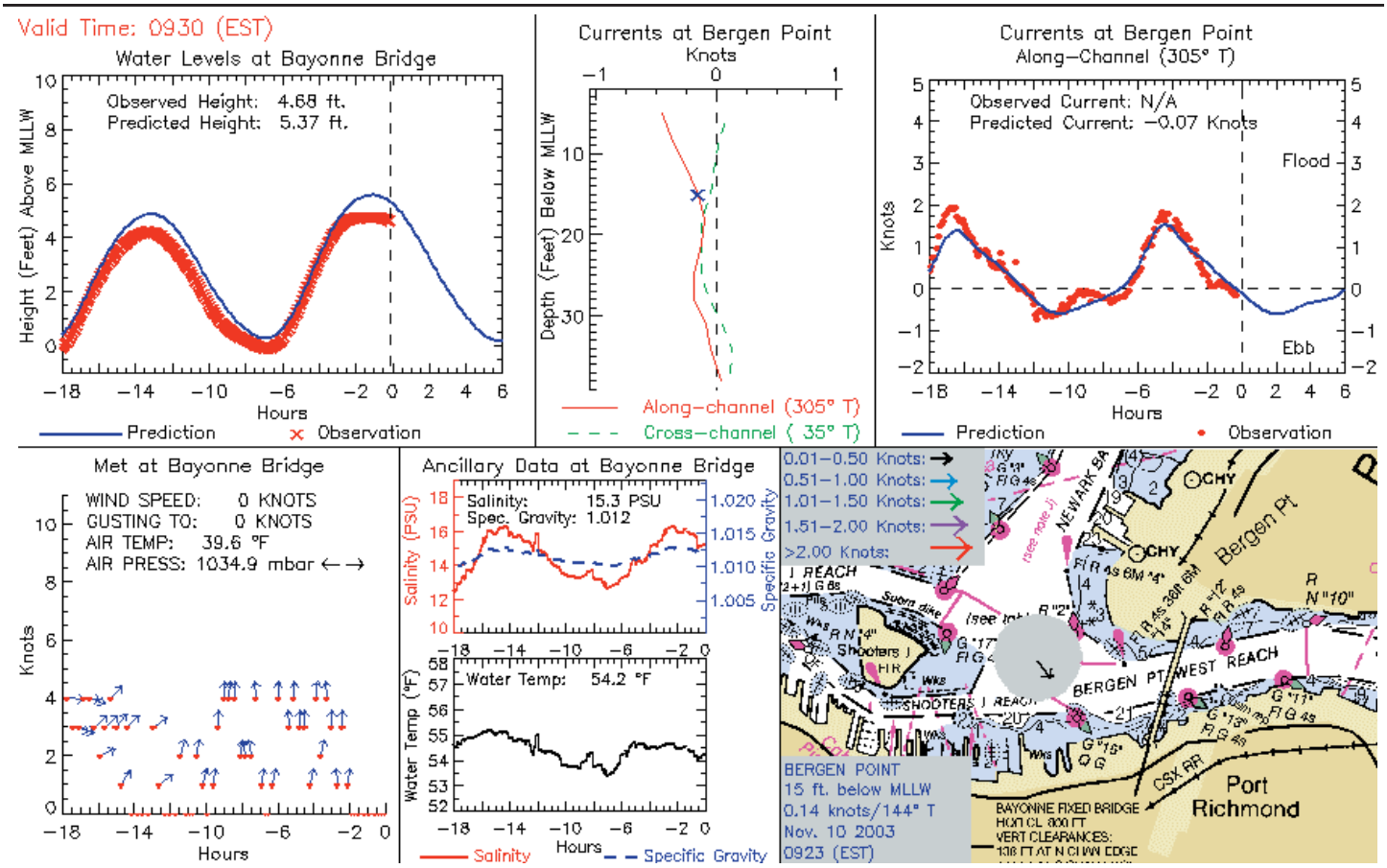


Figure 3-DOC-37. New York/New Jersey PORTS: Bergen Point Composite.

(CBOFS) is an NOS project that provides forecasts of total water level within the Bay in addition to the astronomical tidal prediction. The New York/New Jersey Harbor nowcast/forecast model came on line in 2003, followed by a Houston/Galveston Bay nowcast/forecast model in 2004. Newer models include the St. Johns River, FL and the Great Lakes. In cooperation with OAR and NWS, the NOS CO-OPS now runs 5 models as part of the Great Lakes Operational Forecast System (GLOFS) providing forecast guidance for water level, wind, currents and water temperature. Also, ongoing research will enable PORTS® or similar systems to incorporate biological and chemical sensor systems and forecast models as required and integrate the information with circulation measurements to provide information on transports of materials in the ecosystem essential for effective marine resource management and homeland security.

NOS CONTINUOUS REAL-TIME MONITORING SYSTEM (CORMS)

CORMS was designed to operate on a 24hour/7 days a week basis to ensure the accuracy and working status of tide and current observations acquired via the NWLON and PORTS® programs. CORMS improves the overall data quality assurance of real-time measurements, reduces NOAA's potential liability from disseminating inadequate data, and makes the observations more useful for all applications. CORMS ingests real-time data from all field sensors and systems, including the operational nowcast/forecast models, determines data quality, and identifies and communicates the presence of invalid or suspect data to real-time users/customers who rely on the data (Figure 3-DOC-38). CORMS is especially vigilant during storm and tsunami events to ensure the full set of products and services is being disseminated in a timely fashion. An advanced version of this system, CORMS AI, is presently in developmental stages.

Figure 3-DOC-38. PORTS sites in the New York and New Jersey linked by CORMS.

NOAA Marine and Aviation Operations (NMAO) operates a wide variety of specialized ships and aircraft to support NOAA mission goals. NOAA's ship fleet includes oceanographic and atmospheric research vessels. NOAA's aircraft fleet includes aircraft that collect environmental and geographic data essential to NOAA hurricane and other severe weather and atmospheric research; and aircraft that conduct aerial surveys for hydrologic research for forecasting flooding potential from snow melt.

Figure 3-DOC-40. NOAA Ship KA'IMIMOANA

NOAA SHIPS SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA Ship *RONALD H. BROWN* (Figure 3-DOC-39), an oceanographic and atmospheric research platform, is the largest vessel in the NOAA fleet (274 feet). With its instruments and sensors, *RONALD H. BROWN* travels worldwide supporting scientific studies to increase our understanding of the world's oceans and climate. An advanced meteorological scientific Doppler radar makes the ship a unique attribute to the research fleet.

NOAA Ship *KA'IMIMOANA* (Figure 3-DOC-40) primarily supports the research programs of NOAA's Tropical Atmosphere Ocean (TAO) Project (real-time data from moored ocean buoys for improved detection, understanding and prediction of El Niño and La Niña). These research programs are designed to improve our understanding of the role of the tropical ocean in the world's climate. The ship deploys, recovers, and services deep sea moorings that measure ocean currents, ocean temperatures, and atmospheric variables, throughout the equatorial Pacific Ocean. In addition to data from these moorings, the ship measures upper ocean currents, surface salinity, carbon dioxide content, and takes upper air atmospheric soundings while underway.

The *RONALD H. BROWN* and *KA'IMIMOANA* annually support the Tropical Atmospheric Ocean (TAO) Array by servicing approximately 60 ATLAS and current meter moorings in the central and eastern equatorial Pacific.

In FY 2007, the *RONALD H. BROWN* will work in cooperation with the Woods Hole Oceanographic Institute to conduct mooring recovery and deployment operations of the Stratus Ocean Reference Station (the sixth setting) under the stratocumulus clouds off Chile and Peru. The ship will conduct meteorological and air-sea flux observations to document and establish the accuracy of the moored metrological observations, and to observe the oceanic and atmospheric variability. This region is of critical importance to climate predictability. Additionally, during the project the *RONALD H. BROWN* will support the Chilean Navy in the recovery and deployment of a DART (Tsunami) mooring.

The *RONALD H. BROWN* will again conduct the African Monsoon Multi-

Figure 3-DOC-39. NOAA Ship RONALD H. BROWN

disciplinary Analysis study in FY 2007 to improve understanding of the West African monsoon and its influence both on the regional environment as well as its role in Atlantic Tropical cyclone development. In addition, the ship will be conducting a CO2 tracer study along the East Coast of the U.S..

In FY 2007, the *RONALD H. BROWN* will work with the Woods Hole Oceanographic Institute to conduct mooring deployment (seventh setting) and recovery operations of the Northwest Tropical Atlantic Station located approximately 500NM southwest of Barbados. Data will be simultaneously logged between the sixth and seventh mooring and the ships meteorological suite during several hour long inter-comparison periods.

NMAO supports the National Data Buoy Center (NDBC) on an as-needed basis in the recovery of meteorological and environmental monitoring buoys that have been disabled or become adrift. In FY 2005, NMAO diverted four ships for a total of 20 sea days in support of NDBC buoy recoveries. In FY 2006, NMAO will continue to provide support to NDBC for recovery of buoys that come adrift as necessary when ship schedules permit.

NOAA AIRCRAFT SUPPORTING METEOROLOGICAL ACTIVITIES

NOAA aircraft support a broad range of meteorological activities and projects with its fleet of aircraft based at MacDill Air Force Base in Tampa, Florida. Three of its eleven aircraft are dedicated to this purpose throughout the year, providing valuable information to NOAA and the nation.

For these three aircraft, the 2005 hurricane season was the busiest on record. Operating from bases in Florida, Georgia, Costa Rica, the U.S. Virgin Islands and Barbados, the NOAA Gulfstream G-IV (SP) and two WP-3D Lockheed Orion aircraft flew 123 missions for a total of 897 hours. The data collected and transmitted from these aircraft during the season made a significant positive impact on hurricane forecasts and warnings during Hurricane Dennis, Emily, Katrina, Ophelia, Rita and Wilma.

The NOAA Gulfstream, G-IV (SP) (N49RF), provides scientists with a platform for the investigation of processes in the upper troposphere and lower stratosphere (Figure 3-DOC-41). With an operating ceiling of 45,000 ft, the G-IV (SP) is a critical tool for obtaining the data necessary to improve hurricane and winter storm track forecasts and for research leading to improvements in hurricane intensity forecasts. The G-IV (SP) is also being used for air chemistry studies where a high altitude capability is required. In 2006, researchers studying the role of Saharan dust on tropical storm development and intensity also used this aircraft.

The NOAA G-IV (SP) annually supports Hurricane Synoptic Surveillance missions where the aircraft flies in the environment surrounding the storm at a high altitude releasing GPS dropsondes at pre-selected locations (Figure 3-DOC-42). The data from these vertical atmospheric soundings are transmitted from the aircraft to the NCEP computer site where they are incorporated into the hurricane computer models to improve hurricane track forecasts. The dropsonde directly measures temperature, pressure, and humidity as it falls through the atmosphere to the surface, and computes wind speed and wind direction using a full-up GPS receiver.

Recent estimates of the improvement in hurricane track predictions utilizing this aircraft and dropsonde are between 20 and 30 percent, resulting in a savings of $10 million or more per hurricane in warning and preparedness costs. In 2005, the 48-hour improvement in track forecasts for Hurricanes Katrina and Rita were 40 and 30 percent respectively.

The NOAA G-IV (SP) also annually supports the Winter Storms Reconnaissance Program in an effort to improve forecasts released 24 to 96 hours before winter storms in the U.S.. This aircraft, in conjunction with the Air Force Reserve's WC-130s, utilize the GPS dropsondes to collect data on developing severe winter storms over the Pacific Ocean that will seriously impact the continental U.S. and Alaska. During one month of the two-month season, both aircraft operate in tandem, one from Alaska and the other from Hawaii, to collect data both north and south of the jet stream simultaneously. General improvement in forecast accuracy of up to 20 percent has already been seen, and even higher percentage improvements on individually targeted events have been realized from this program. Typically, during the final month of the program, the NOAA G-IV (SP) operates independently from either the base in Alaska or Hawaii as the case may dictate.

A recent additional mission for the G-IV (SP) was the support of the Saharan Air Layer Experiment (SALEX). The outbreaks of dry Saharan dust has been shown to have a dampening effect on the development of tropical cyclones in the Atlantic, and the G-IV (SP), with its high altitude and dropsonde capabilities, is the ideal tool to study this phenomenon. Operating from Barbados, the most easterly island in the western Atlantic, this aircraft flew four missions in 2005 on an initial study of the dust outbreaks, and

Figure 3-DOC-41. NOAA Gulfstream G-IV (SP)

it returned to Barbados in 2006, along with a NOAA WP-3D aircraft, to continue this important work.

NOAA's Aeronomy Lab, located in Boulder, CO, is presently expanding its air chemistry capabilities on the G-IV (SP) beyond just ozone measurements with the addition of a proton transfer reaction mass spectrometer (PTR_MS). The PTR_MS provides in-situ measurements of volatile organic compounds (VOCs). A second instrument, which measure carbon monoxide (CO), is also being tested aboard the aircraft. Beyond just their dedicated research, lab scientists also hope to piggyback on missions during the 2006 hurricane season.

NOAA's atmospheric and oceanographic research, as well as its reconnaissance operations, is supported by two WP-3D Lockheed Orion aircraft (N42RF and N43RF) which carry a full array of state-of-the-art environmental research instrumentation (Figure 3-DOC-43). The aircraft research and navigation systems provide detailed spatial and temporal observations of a wide range of atmospheric and oceanic parameters. NOAA's Aircraft Operations Center (AOC) develops and calibrates specialized instruments, integrates user-supplied instrumentation into its automated data recording systems, and processes and analyzes data sets collected during various field programs.

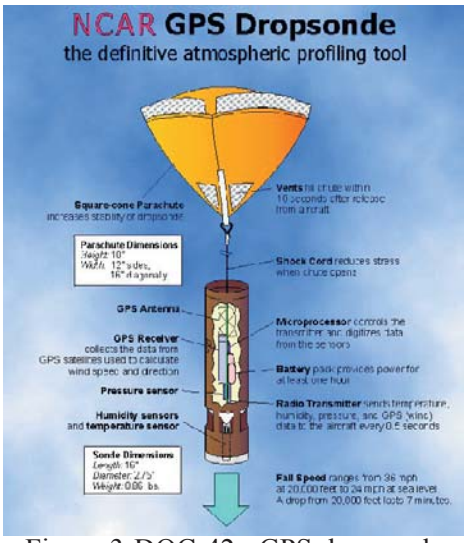


Figure 3-DOC-42. GPS dropsonde

The AOC WP-3D aircraft, while executing the complex patterns for hurricane research, also provided storm data to the National Hurricane Center (NHC) in near, real-time, transmitting flight level data, GPS dropsonde messages, as well as radar images via its multiple aircraft-satellite data links. With the Stepped Frequency Microwave Radiometers (SFMR) coming online operationally during FY 2005, increasing emphasis has been placed on utilizing the NOAA WP-3Ds to map the surface wind fields in and around hurricanes and tropical storms. Real-time surface wind speed maps are critical to providing more accurate forecasts of the extent of hurricane and storm force winds.

The AOC aircraft also augment the Air Force Reserve reconnaissance aircraft during particularly active storm periods when tasking requirements exceed their available resources.

Each year, one of the NOAA WP-3Ds participates in a Hurricane Awareness Tour targeting, alternately, the Gulf and East coast regions of the U.S., those areas that are most vulnerable to land-falling storms. This educational outreach effort is directed at both middle-grade school children, the age group most likely to see, learn and convey a message home, as well as the general public. These tours are operated in concert with the participation of officials from the NHC, the Red Cross, FEMA and other local and state emergency management personnel. This is becoming an increasingly more popular and successful venture as coastal populations grow and the threat of an increasing number of storms place more people in harm's way.

During the 2005 season, the two NOAA WP-3Ds supported three major research experiments. In support of NOAA's Hurricane Research Division, these aircraft participated in the Intensity Forecast Experiment (IFEX), a multi-year endeavor to study the life cycle of hurricanes from pre-depression to mature land-falling stage in order to better characterize their structure and dynamics with the objective of improving intensity forecasts. During the 2005 season, the NOAA research team was fortunate to obtain complete life cycle data sets on five hurricanes, Dennis, Emily Katrina, Ophelia and Rita. While some effort will be made during the 2006 season to continue these observations, the major emphasis will be shifted to a study of the impact of Saharan dust on the development of tropical storms.

In collaboration with NASA and its ER-2 aircraft, NOAA utilized the two WP-3Ds in support of the Tropical Cloud Systems and Processes (TCSP) study. In an experiment that focused mostly on the genesis of tropical storms, the two aircraft were based for a three-week period in Costa Rica, flying missions in the Caribbean, Gulf of Mexico and eastern Pacific in concert with the ER-2 aircraft.

Figure 3-DOC-43. NOAA WP-3 Orion

Following TCSP, NOAA scientists used the two WP-3Ds in collaboration with scientists from NSF's National Center for Atmospheric Research (NCAR) and the Naval Research Laboratory (NRL) in a second major hurricane research experiment in August and September. The Hurricane Rainband and Intensity Change Experiment (RAINEX) was a project focusing on the role that rainbands play in changes to storm intensity. The uniqueness of this experiment, which utilized the Tail

Doppler radars from the two NOAA WP-3Ds and the ELDRA Tail Doppler radar on the NRL P-3, was the satisfactory fulfillment of the requirement to provide flight track data and lower fuselage radar imagery from the two NOAA aircraft to the NRL P-3 at a frequency of at least once every 15 minutes.

Pilots on the NRL P-3 aircraft, which was operating with only forward-looking nose radar, required this information in order to safely and effectively operate in the hurricane environment with the NOAA aircraft. This was accomplished utilizing high-speed satellite communications to stream radar imagery and flight level data from the NOAA aircraft to ground computers where it was reformatted and transmitted to the NRL aircraft. Because of the success of this effort, valuable data sets were obtained in Hurricanes Katrina, Ophelia and Rita.

Tropical to extra-tropical transition was the focus in Hurricane Ophelia as one of the NOAA WP-3Ds flew several missions into that storm as it moved northward over the cooler waters of the north Atlantic during the middle of September, 2005. Operating initially from MacDill AFB in Tampa, FL, and later from Pease Air Base in Portsmouth, NH, N42RF flew several missions as far north as Canadian airspace east of Nova Scotia collecting data for one of HRD's research objectives, that being the decay of tropical systems to an extra-tropical state over cooler water.

The NOAA WP-3Ds annually support both a summer and winter operation in support of a NESDIS satellite validation program. Operating in regions of high winds and heavy precipitation, one of the WP-3Ds, equipped with microwave scatterometers and radiometers, provide flight validation of NOAA QuickScat and WindSat sensed ocean surface wind vectors. Traditional venues for these operations are Alaska or Newfoundland in the winter and the Atlantic and Caribbean regions during the summer hurricane season.

Every other year, one of the NOAA WP-3Ds participates in an intensive air chemistry program, usually in concert with a number of other Federal agencies and universities. During July 2004, N42RF participated in the New England Air Quality Study (NEAQS) along with a number of other aircraft, ground stations, and the NOAA Ship *RONALD H. BROWN*. During the summer of 2006, N43RF is scheduled to join several other aircraft operating in the Houston area and the *RONALD H. BROWN* operating in the Gulf of Mexico in the Texas Air Quality Study. Packed completely with an impressive array of in-situ chemical samplers and three instrument pods mounted beneath its wings, the aircraft will take measurements of a wide range of chemical constituents at low altitudes over the urban and rural landmass as well as the marine boundary layer. Additionally, atmospheric profiles were made from the surface to the maximum altitude capability of the aircraft (~25,000 ft).

During FY 2006, one of the NOAA WP-3Ds completed the Atmospheric Rivers Project over the Pacific northeast of the Hawaiian Islands. As part of the NOAA's weather-climate program, this project focused on documenting the flow of moisture moving is a northeasterly direction toward the U.S. mainland - measurements that are critical to both the global water cycle and to storm prediction.

A NOAA AC-695A Commander 1000 (N45RF) and a NOAA AC-500 Shrike (N51RF) are used annually to conduct important snow pack surveys in the northern and western continental U.S., Alaska, and southern Canada (Figure 3-DOC-44). During these survey flights, the gamma radiation sensors aboard these aircraft measure the naturally occurring terrestrial radiation emitted from the ground to obtain snow water-equivalent estimates. This data is transmitted to the National Operational Hydrologic Remote Sensing Center (NOHRSC) up to three times a day from each aircraft, and after further processing the data is distributed to NWS field offices within five minutes of receipt from each aircraft. These data are used by the NWS to forecast river levels and potential flood events resulting from snowmelt water runoff. Hydroelectric power interests and other water supply managers also use the data to regulate water storage and delivery.

Figure 3-DOC-44. NOAA JetProp Commander - N45RF.

SECTION 3

DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates military environmental services to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces and joint operations. Military environmental services directly support all phases of military operations from strategic planning to tactical operations. While the Army and Marine Corps each have a small weather operations capability, the Navy and Air Force are the primary sources of military weather products and services. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea, where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite Program to meet unique military requirements. Observational data are sent through military communications systems to military and civil facilities in the United States and overseas.

UNITED STATES AIR FORCE

METEOROLOGICAL AND SPACE ENVIRONMENTAL SERVICES

Air Force Weather (AFW) forces provide high-quality, mission-tailored terrestrial and space environment observations, forecasts, and services to the United States Air Force (USAF), United States Army (USA), and a variety of United States Government (USG) departments and agencies. See Section 3, *United States Army*, for details of AFW support to the Army.

AIR FORCE WEATHER (AFW) ORGANIZATION

AFW is functionally organized under the Director of Weather (AF/A3O-W), Directorate of Current Operations and Training (AF/A3O), Deputy Chief of Staff for Air, Space, and Information Operations, Plans and Requirements (AF/A3/A5), Headquarters Air Force (HAF). The Director of Weather oversees AF-wide training, organizing, and equipping of AF weather organizations to include the following functions:

- Development of doctrine, policies, requirements, and standards for weather support,
- Evaluation of weather support effectiveness,
- Management of weather officer, enlisted, and civilian career fields,
- Development and implementation of mid- to long-range plans for the organization, equipment, manpower, and technology necessary to meet future AF and Army weather requirements,
- Advising Air Staff and subordinate headquarters weather functional managers regarding manpower, career field management, personnel utilization, training, operations policy and procedures, and technology acquisition,

6. Advocating and fielding standardized weather equipment.

AFW oversees operations that provide a Total Force capability employing over 4,200 Active and Reserve Component (AC and RC) military and civilian personnel supporting AF and Army conventional and special operations forces (SOF) worldwide. The majority of AF weather personnel are focused on two distinct, yet related functions: *characterizing the past, current, and future state of the natural environment and exploiting environmental information to provide actionable environmental impacts information directly to decision-makers*.

Environmental characterization is typically accomplished in large, centralized units focused primarily on global and regional scales of weather, whereas support to decision-makers is primarily the realm of personnel embedded in operational units. Normally, these personnel are assigned to weather flights under the operations support squadron of a flying wing, a

weather squadron collocated with a supported Army unit, or a weather squadron providing a unique capability such as space launch support. These weather squadrons may include geographically separated detachments and operating locations.

The centerpiece of global-scale collection and production is the Air Force Weather Agency (AFWA), Offutt AFB, Nebraska, a field operating agency (FOA) reporting directly to the AF Director of Weather. AFWA provides timely, accurate, relevant, and consistent terrestrial and space weather products necessary to effectively plan and conduct military operations at all levels of war. AFWA also provides dedicated support to SOF and the Intelligence Community (IC). The agency consists of a global processing center collocated with a functional management headquarters, the 1st Weather Group (1 WXG) with four subordinate CONUS Operational Weather Squadrons (OWS), two subordinate centers (the Air Force Combat Climatology Center (AFCCC) and the Air Force Combat Weather Center (AFCWC)), and 11 detachments and operating locations. AFWA also provides backup support to five national weather centers.

The 1 WXG commands four OWSs performing CONUS missions: 15 OWS at Scott AFB, IL; 26 OWS at Barksdale AFB, LA; 25 OWS at Davis-Monthan AFB, AZ; and 9 OWS at Shaw AFB, SC. AFCCC, Asheville, North Carolina, provides centralized climatological database services, produces specialized weather-impact information for DOD and allied nations, and warehouses and distributes atmospheric science-related technical information. From Hurlburt Field, Florida, AFCWC transitions technology to support tactical-level weather operations while developing operational concepts, tactics, techniques, and procedures.

Eight OWSs form the backbone of regionally focused weather operations, providing a variety of weather forecast products and support to units assigned and/or deployed into their area of responsibility (AOR). These AORs are currently under revision to better align with the recently activated 1 WXG. The A3O-W proposed AORs are depicted in Figure 3-DOD-1. OWSs produce and disseminate terminal aerodrome forecasts (TAFs), weather watches, warnings, and advisories, planning and execution area forecasts, and other products using the OWS Pro-

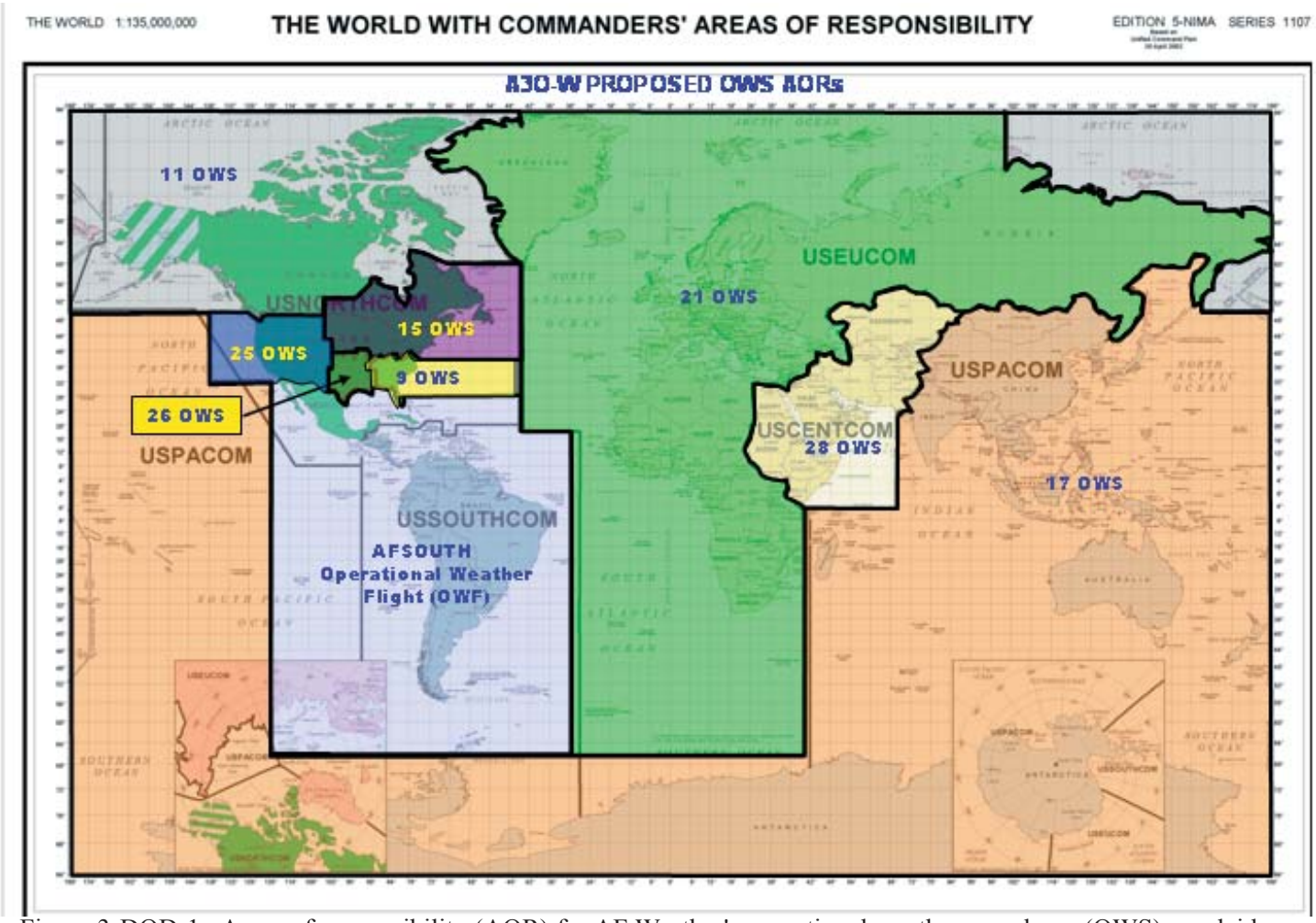


Figure 3-DOD-1. Areas of responsibility (AOR) for AF Weather's operational weather squadrons (OWS) overlaid on geographic combatant commander AORs.

duction System Phase II (OPS II). OWSs also provide theater-scale, tailored environmental information to guide development of mission execution forecasts (MEF) by AC and RC weather personnel embedded in operational units. Moreover, OWSs provide flight weather briefings to aircrews operating within their AOR without home station support or as requested by base or post-level weather forces.

At base and post level, AFW forces take and disseminate local observations and develop tailored MEFs based on centrally produced guidance. These personnel also act as "eyes forward" for OWSs. Weather personnel supporting conventional AF operations typically deploy with a New Tactical Forecast System (N-TFS), hand-held Kestrel observing kits, and the TMQ-53 semi-automated observing system for semi-permanent sites. This equipment, coupled with adequate communications to receive weather data, including satellite imagery, provide the essential capability required for deployed weather forces to meet operational requirements.

The RC is composed of the Air Force Reserve (AFR) and the Air National Guard (ANG), and AFW continues to reengineer these forces to more closely align with AC weather operations. AF reservists augment the AC at all levels. To augment OWSs, AF Reserve Command recently organized two operational weather flights (OWF), each with just over 20 traditional reserve positions. The OWF traditional reservists perform at least one weekend of drill monthly and 2 weeks of duty each year, unless mobilized to the active force. Approximately 50 additional weather personnel serve as AFR individual mobilization augmentees (IMAs) assigned to various active AFW organizations at all echelons, typically in staff or scientific roles. IMAs normally train 1 day each month and for an additional 2 weeks each year.

The ANG traditional program consists of 27 weather flights, ranging in size from 13 to 25 personnel, who meet monthly to train for their wartime mission. These flights provide weather information to Army National Guard and U.S. Army Reserve units. Many ANG flying wings also have up to five personnel to provide weather support for each wing's flying mission. The ANG also provides peacetime weather support at locations where the ANG is responsible for airfield support. The Weather Readiness Training Center (WRTC) at Camp Blanding, near Starke, Florida, is also operated by the ANG to provide weather support operations training.

CHARACTERIZE THE ENVIRONMENT

To characterize the environment across the globe, AFW forces continually improve the core processes of collection, analysis, and prediction.

Collection

AFW forces collect terrestrial and space environmental measurements from ground-, sea-, air-, and space-based sensors across the globe. While openly shared foreign data greatly improves the coverage of measurements across the globe, the Department of Defense retains an assured global weather collection capability. In regions where air, space, and land operations are occurring, indigenous environmental data may be insufficient; consequently, the AF maintains a capability to deploy in-theater to establish an environmental data collection network.

AFW personnel take observations essential for effective military operations and for weather analysis and forecasting. Weather personnel at both AF and Army locations (garrison and deployed) make observations available to local users and transmit them to military and civil locations throughout the world. U.S. and foreign rawinsonde reports are primary sources of upper air observations and are supplemented with military and civilian pilot reports. The Army's Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARTYMET) program augment AF observations in the tactical environment. Weather data is also received from DOD-operated HF radio receiver sites strategically positioned around the globe to intercept weather broadcasts. These broadcasts originate from nations that do not routinely make data available through World Meteorological Organization (WMO) channels.

The Observing System 21st Century (OS-21) program will provide a much-needed, state-of-the-art life-cycle replacement for AF observing equipment. OS-21 includes five different configurations: fixed, deployable, remote, manual, and upper air. The manual configuration is intended for tactical operations and continues the improvements begun under the AFW Manual Observing System and Tactical Meteorological Observing System Modification programs. AFW began fielding the fixed-base automated observing system and will continue to do so through 2007. The remaining configurations will be upgraded or replaced after fielding of fixed-base automated systems nears completion.

Weather radar data is vital to the production of timely severe weather warnings. DOD, the Federal Aviation Administration (FAA), and Department of Commerce (DOC)/National Weather Service (NWS) operate and maintain WSR-88Ds within the Continental United States (CONUS), and the AF operates and maintains several WSR-88Ds overseas. The AF transitioned to the open architecture Open Principal User Processors (OPUPs) at installations with stand-alone legacy PUPs and at all CONUS and PACAF OWSs, allowing these regional forecasting centers real-time access to WSR-88D radar data at locations for which they have remote forecasting

responsibility. Tactical weather radars (TWR) provide fixed Doppler radar coverage for major overseas installations not covered by the WSR-88D. Ellason weather radars (EWR) provide a deployable weather radar capability for worldwide military contingency operations. Weather radar data extracted from air surveillance radars (ASR) and displayed using the Digital Weather Intelligence Data (DWID) system supplement primary weather radar data and provide data from areas without primary weather radar coverage.

The AF Reserve Command's 53d Weather Reconnaissance Squadron (53 WRS), also known as the "Hurricane Hunters," provides another means of collecting vital meteorological data, especially in and around tropical cyclones. Their specially equipped WC-130 aircraft collect temperature, moisture, wind, pressure, and visually observed information at the aircraft location as well as vertical profiles of the atmosphere collected by dropsondes. Hurricane Hunter aircraft penetrate the eyes of tropical cyclones to provide the NWS's National Hurricane Center a very accurate center fix location as well as other meteorological parameters, including sea level pressure (Figure 3-DOD-2). In addition to the tropical cyclone reconnaissance, the 53 WRS collects meteorological information to improve wintertime West Coast forecasts and to support scientific field programs when possible.

The Defense Meteorological Satellite Program (DMSP), which provides cloud, upper air, and space environmental data, is a vital source of global weather data used to support combat operations. On-board sensors provide AFWA and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery, temperature and moisture sounding data, electrically charged particle fluxes, and other

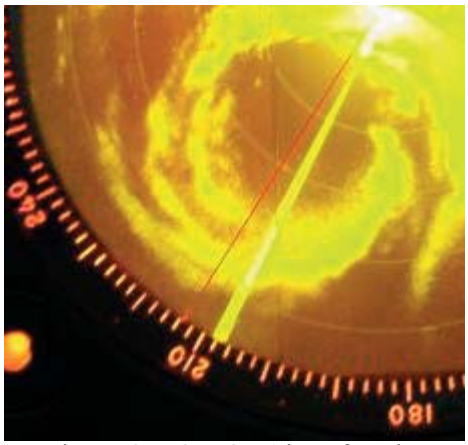


Figure 3-DOD-2. Aircraft radar shows the eye of Hurricane Claudette is 25 nautical miles wide and the wall cloud is weakest in the northeast quadrant (53 WRS website)

specialized space environment data. The DMSP also supplies direct, real-time readout of regional imagery and mission-sensor data to DOD land-based and shipboard terminals located worldwide (Figure 3-DOD-3).

The DMSP satellite constellation uses the Operational Linescan System (OLS) to provide visible and infrared imagery to distinguish between clouds, ground, snow, and water. The Block 5D-2 series spacecraft flies the Special Sensor Microwave Temperature (SSM/T-1) and water vapor (SSM/T-2) sounders. Processing algorithms convert the sensed data into vertical temperature, moisture, and height profiles of the atmosphere, providing key data for numerical analysis and forecasting. The Special Sensor Microwave Imager (SSM/I) collects data from which rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data can be determined. The Special Sensor for Ions and Electrons (SSIES), Special Sensor Magnetometer (SSM), and the Precipitating Electron and Ion Spectrometer (SSJ), measure the space environment on the topside of the ionosphere in situ. The Block 5D-3 series spacecraft and sensor suite began service in 2004, with the launch of DMSP Flight 16. These spacecraft add several new capabilities: enhanced microwave imaging and atmospheric temperature/moisture sounding through the Special Sensor Microwave Imager/Sounder (SSMIS); new auroral boundary and electron density measuring capability through the Special Sensor Ultraviolet Spectrographic Imager (SSUSI); and profiles of upper-atmospheric temperature, electron content, and species densities through the Special Sensor Ultraviolet Limb Imager (SSULI). These are in addition to SSIES, SSM, and SSJ sensors.

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) will replace the existing DMSP and NOAA polar-orbiting satellite programs beginning in 2013, and is a joint DOD, DOC, and National Aeronautics and Space Administration (NASA) program. The AF also expects to gain operational experience as well as benefit from the risk reduction planned with the NPOESS Preparatory Program planned for launch in 2010. (Note: In January 2006, the program was expected to exceed its approved program baseline by 25 percent. This required the DOD to recertify the program to Congress in accordance with the Nunn-McCurdy Amendment of the 1982 Defense

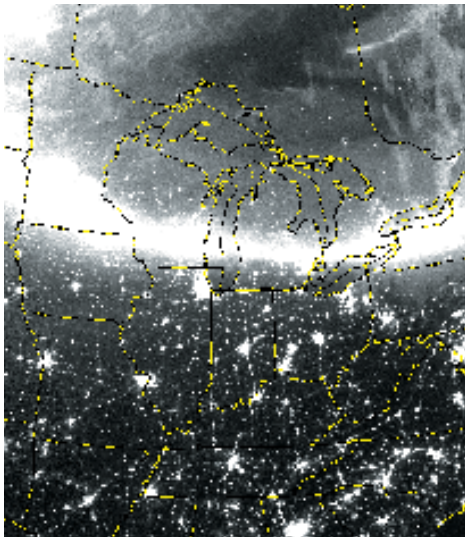


Figure 3-DOD-3. DMSP captures Aurora Borealis, over the midwest; the aurora was pushed toward the equator by a November 4, 2003 geomagnetic storm. (AF Weather website)

Authorization Act. AFWA hosted and provided information on operations and requirements to Integrated Product Team 2 (IPT-2). IPT-2 is charged with assessing alternatives for the program. The final program configuration, including the number of platforms and sensors, is yet to be determined.)

In addition to DMSP polar-orbiting data, AFWA receives stored data from the DOC's Polar-orbiting Operational Environmental Satellite constellation and real-time high-resolution data from the DOC's Geostationary Operational Environmental Satellite (GOES) East and West; the European Union's Meteosat-5, -7, -8 and -9 geostationary satellites; and the Japanese Multi-functional Transport Satellite (MTSAT). AFWA currently receives data from NASA's Tropical Rainfall Measuring Mission (TRMM), Quick Scatterometer (QuikSCAT), and AQUA Advanced Microwave Scanning Radiometer-E (AMSR-E) via Direct Asynchronous Transfer Mode (ATM) System-Unclass (DATMS-U). Moderate Resolution Imaging Spectroradiometer (MODIS) data is currently received via the Defense Research Engineering Network (DREN).

AFW implemented the Joint METSAT Imagery, Software, and Terminals (JMIST) capability to receive real-time visible, infrared, and microwave imagery and other non-imagery weather data from both polar-orbiting and geostationary satellites. JMIST employs network and satellite communications, MARK NB and Receiving Set Satellite (RSS) direct read-out terminals, and client applications to provide ready access and manipulation capabilities for advanced low-orbiting satellite imagery to numerous agencies, to include the U.S. Air Force, U.S. Navy, U.S. Army, U.S. Marines, NOAA and NASA. JMIST also provides a stand-alone geostationary METSAT Direct Readout Terminal (DRT) and a Direct Readout Satellite Receiver (DRSR) for mobile units with insufficient network communications to employ reach-back methods.

Next generation satellite programs, in particular NPOESS and GOES-R, require AFWA to reengineer the way it receives, stores, and processes METSAT data, as well as how it exposes and delivers that data to internal and external users. AFWA is partnering with Electronic Systems Command (ESC) in 2006, to initiate the NPOESS Data Exploitation Study. The primary outputs of the study will include a way ahead for processing and storing NPOESS data at AFWA, a way ahead for exposing and delivering METSAT data including NPOESS to command and control (C2) and other users, an analysis of alternatives for the "to be" enterprise software and system architecture for exploitation of data from current and programmed satellites, and a recommended phased approach necessary for AFWA to modify systems to meet the "to be" software and system architecture for exploitation of data from current and programmed satellites. The study is scheduled to begin in the summer of 2006, and last for nine months.

Space environmental information is obtained through a combination of ground- and space-based systems. For the near-Earth environment, ground-based systems provide highly accurate point source verification and specification, whereas space-based systems enable global coverage and theater-wide situational awareness.

AFWA operates the Solar Electro-optical Observing Network (SEON), a system of ground-based telescopes at Sagamore Hill, Massachusetts; Holloman AFB, New Mexico; Palehua, Hawaii; San Vito, Italy; and Learmonth, Australia (Figure 3-DOD-4). This network provides 24-hour observations of solar phenomena at optical and radio wavelengths. A worldwide (primarily Northern Hemisphere) network of ground-based ionosondes and other sensors provide ionospheric data. The AF manages 16 automated Digital Ionospheric Sounding Systems (DISS) to measure electron density profiles in the ionosphere. NASA's Jet Propulsion Laboratory (JPL) operates a complementary global network of over 125 sensors deriving ionospheric line-of-sight Total Electron Content (TEC) from GPS signals and provides these data to AFWA's Space Weather Branch. In addition, the United States Geological Survey (USGS) operates a network of ground-based magnetometers, primarily in the Northern Hemisphere, which provides the Space Weather Branch with critical measurements of the geomagnetic field and its variances. AF Research Laboratory at Hanscom AFB, MA, provides ionospheric scintillation data from a global network of 15 UHF and L-Band receivers, supporting AF command and control satellite systems and strategic long-range radar systems.

From space, the GOES satellites provide real-time solar X-ray, charged energetic particle, and geomagnetic data through NOAA's Space Environment Center (SEC). The Solar X-Ray Imager (SXI), which became operational January 30, 2003, aboard GOES-12, monitors solar emissions in the X-ray portions of the solar spec-

Figure 3-DOD-4. Solar optical and radio telescopes at Learmonth, Australia.

trum and provides near real-time display at AFWA and the SEC. DMSP, NOAA, and other DOD geostationary satellites provide charged energetic particle data in low-Earth and geosynchronous orbits. Additionally, the AF leverages space-based data from NASA and other agencies. For example, NASA's Advanced Composition Explorer (ACE) satellite provides real-time solar wind data critical for forecasting geomagnetic disturbances and their impact to warfighter communications.

Analysis and Prediction

Effective analysis of collected terrestrial and space weather data enables identification of environmental features and conditions that may affect air, space, and land operations and thus require subsequent monitoring. From that analysis, detailed forecasts are developed through a combination of computer models and skilled human intervention.

AFWA's Global Weather Center Division is the AF's main production capability for global space and terrestrial weather analyses and forecasts. Worldwide conventional weather data are relayed to AFWA and combined with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further process the data to construct models of the atmosphere and forecast its future behavior. The Satellite Data Handling System (SDHS) facilitates the interaction between forecaster and machine.

The Division's Meteorological Satellite (METSAT) Applications Branch analyzes imagery, develops techniques, inserts technology, and recommends improvements to METSAT products. The branch produces rapid response, tailored METSAT imagery and evaluation for DOD contingency operations and generates automated METSAT imagery products for web-based distribution to DOD users. The branch also tracks and classifies tropical cyclones for the DOD Joint Typhoon Warning Center (JTWC) and NOAA's National Hurricane Center; serves as the DOD focal point for volcanic ash plume detection, advisories, and trajectory forecasts; and provides back up for both JTWC satellite operations and the DOC's Washington Volcanic Ash Advisory Center. In addition, the METSAT Applications Branch produces worldwide snow and ice cover analyses to update and refine the snow depth database and generates customized snow depth and dust event analyses for contingency areas. During Operation IRAQI FREEDOM, branch imagery specialists provided high-resolution analyses of oil fire initiation points for smoke plume dispersion forecast model products. These smoke plumes impacted both air and land operations. Advance notice allowed mission planners to modify operations to maximize mission effectiveness. The branch also develops new capabilities to display and visualize satellite imagery on workstations and infuses state-of-the-art techniques into improved imagery analysis.

The Division's Space Weather Branch employs a suite of state-of-the-art space weather models to specify current solar and global characteristics, extrapolate space weather phenomenon to areas of the globe where observations are not currently available, and to forecast future conditions. These models use available observations and include both climatology-based and physics-based algorithms. Some of the more significant models employed include the following:

- A Kp analysis and prediction algorithm provides real-time analysis of Kp and a one and four hour prediction.
- A Dust prediction algorithm provides a one hour Dust forecast.
- The newly implemented Global Assimilation of Ionospheric Measurements (GAIM) model provides large scale, global ionospheric specification every 15 minutes, and a 24 hour forecast capability every hour.
- Scintillation forecasts are provided by the climatology-based WIDEBAND model.
- The Magnetospheric Specification and Forecast Model specifys and predicts (for 3 hours) the lower energy particle environment.
- The newly implemented Radiation Belt Environments (RBE) model provides specification of the higher energy particle environment.
- A 27 day prediction of relativistic electron behavior at geostationary altitude is provided by the relativistic Electron Prediction (REP) model.
- For the solar wind, the branch uses the Hakamada-Akasofu-Fry solar wind model, capable of producing a 96 hour forecast of solar wind parameters, including the tracking of Coronal Mass Ejections (CME's).
- Several other applications are also employed to calculate other important space weather related parameters.

The Global Theater Weather Analysis and Prediction System (GTWAPS) is the hardware enclave (IBM Scalable Parallel Computing and pSeries® servers) used to run most meteorological models at AFWA. The key software component of GTWAPS is a theater analysis and forecast model, Mesoscale Model version 5 (MM5), which provides fine-scale forecasts (Figure 3-DOD-5 on next page). During Operations ENDURING FREEDOM and IRAQI FREEDOM, AFWA initiated various model window locations and resolutions as mission requirements dictated. The highly responsive nature of the MM5, and the way AFWA employs it, permitted new contingency windows to be operational within hours. Advancements in cloud modeling have enabled GTWAPS to produce high-resolution products that became a mainstay of weather data during the continuing global war on terrorism. MM5 is routinely provided by AFWA to NOAA's National Centers for Environmental Prediction (NCEP),

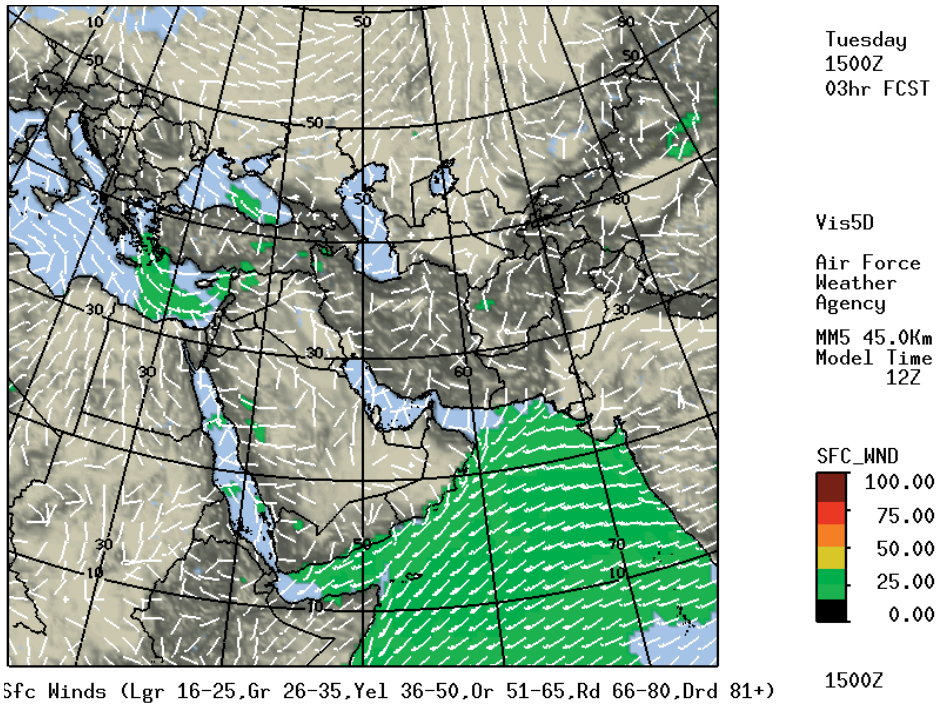


Figure 3-DOD-5. Joint Air Force and Army Weather Information Network (JAAWIN) provide reachback capability for deployed weather forces. This 3-hour forecast of surface winds over Southwest Asia was generated from AFWA's 45-km MM5 (AFWA Website)

where it is a backup to their Eta model.

The future replacement of MM5 will be the Weather Research and Forecast (WRF) model. WRF will possess the responsiveness of MM5 but also has the ability to interchange different microphysics modules within the model. AFWA will leverage this capability to tailor model output for different theaters. AFWA will decommission MM5 windows and replace them with WRF model output. Additionally, AFWA will leverage NCEP's WRF model output for North American regions and run WRF over other areas of the world.

On-going modernization initiatives at AFWA include the Space Weather Analysis and Forecasting System (SWAFS) and the Weather Data Analysis Capabilities (WDAC) program. SWAFS will integrate additional space weather data sources and execute next-generation space weather models for DOD and IC operations. WDAC will continue the modernization of AFWA as a key component of the Air Force Weather Weapon System (AFWWS). The reengineered AFWA will provide standards-compliant hardware and software tools, a central 4-D database, and a classified processing environment to modernize the AFWWS communications and data processing infrastructure. WDAC provides a significant increase in the database capability by standing up Joint DOD-approved METOC database segments, promoting interoperability among data sharers. WDAC, through the use of the Joint METOC segments and the Joint METOC Broker Language (JMBL) for web services, will improve the interoperability with DOD command and control (C2) and command, control, communications, computer, intelligence, surveillance, and reconnaissance (C4ISR) systems by providing a common interface to request the wide range of weather information. In addition, WDAC-developed components, including the Consolidated Dissemination Capability (subscription services), are reusable within the OWS. This reusability will allow OWS-unique data to become part of the overall AFWWS 4-D database.

The Air Force Combat Climatology Center (AFCCC) is collocated with NOAA's National Climatic Data Center to facilitate cooperation and data exchange. AFCCC collects, quality assures, and assesses worldwide surface and upper air observations, satellite-derived soundings, numerical model output such as global gridded surface and upper air model data, a global 3-dimensional cloud analysis (worldwide merged cloud analysis), a global analysis of snow cover, and other specialized environmental data sets. AFCCC exploits these data to generate standard climatic summaries of meteorological phenomena for points around the globe, such as Operational Climatic Data Summaries and Wind Stratified Conditional Climatologies. Modeled climatologies are produced using the Advanced Climate Modeling and Environmental Simulations (ACMES) model. Analysts are available to develop tailored products to meet new requirements. AFCCC employs the Point Analysis Intelligence System (PAIS) to produce vertical profiles for any point on Earth for any time from 1985 to the present.

The AF Director of Weather is the DOD Air and Space Natural Environment Modeling and Simulation Executive Agent (ASNE MSEA). The Director executes this responsibility through the ASNE MSEA office, a division within AFCCC (AFCCC/SM). The executive agent is responsible for ensuring modeling and simulation developers and users have the tools, infrastructure, and databases necessary to represent the air and space natural environment. AFCCC/SM sponsors research and development and fields technology at AFCCC, the designated center providing tailored atmospheric data for modeling and simulation. AFCCC fielded the Environmental Scenario Generator (ESG) capability

in 2005, to support modeling and simulation. In cooperation with the National Geophysical Data Center (NGDC) and the Defense Modeling and Simulation Office (DMSO), AFCCC/SM also sponsors ongoing research to develop a similar capability to provide tailored on-demand representations of the space environment.

AFW's OWSs are regional/theater analysis and forecast centers for AF and Army operations. OWSs generate a variety of products: hazard charts; drop zone, range, and aerial refueling track forecasts; fine-scale target forecasts; airfield forecasts; and weather warnings, watches, and advisories for AF and Army installations within their AOR. OPS II, a component of the Forecasting System 21st Century (FS-21i) program to provide necessary computer hardware and software throughout the AFWWS, is the OWS's primary production tool. A hybrid of software, databases, servers, and workstations, OPS II facilitates production and dissemination of weather information to supported forces.

Provide Actionable Environmental Impacts Information to Decision Makers

To provide actionable environmental impacts, AF weather forces continually improve the core processes of tailoring and integration.

Tailoring. Once centralized weather units create a depiction of the past, current, and future state of the natural environment, AFW forces directly supporting decision-makers tailor the information to identify impacts to operations, personnel, weapons and weapons systems, and tactics. These weather forces then help decision makers mitigate these effects through appropriate actions such as routing a flight to a new target, selecting a different weapons load, or adjusting the time of attack.

N-TFS, another component of FS-21, provides garrison and deployed weather forces with the meteorological tools to manipulate and disseminate graphical and alphanumeric products (satellite imagery, graphical forecast products, weather forecasts, advisories, briefings, observations, etc.) to Army and AF operational, C2, and support forces worldwide. Additionally, N-TFS ingests data from AF and indigenous observing sources, which then are forwarded to OWSs/AFWA for further dissemination and incorporation into centrally produced models.

AFW is currently working toward a single workstation that will eliminate redundancies/inefficiencies and ultimately extend, consolidate and/or replace the OPS II, JWIS, N-TFS, and the weather effects decision-aids portion of the Integrated Meteorological System (IMETS). The Joint Environmental Toolkit (JET) is expected to enhance warfighter awareness of the natural battlespace environment by ensuring accurate, timely, relevant, and consistent terrestrial and space weather and weather impacts information is available and accessible by appropriate personnel and processes. JET will perform its functions by interfacing with information contained in the Virtual Joint Meteorological Oceanographic (METOC) Database (VJMDB) via common-user-communications. Additionally, JET will integrate with joint and coalition command and control and mission planning systems by enabling machine-to-machine exchange of METOC and C4ISR data and information to meet operational, planning and execution requirements. Furthermore, JET enhances the accuracy and utility of terrestrial/space weather and oceanographic information and operational impacts by enabling the forecaster and/or forecast process to incorporate Geographic Information System (GIS) capabilities (to include a standard high-resolution topographic database), forecasting rules of thumb, and operational thresholds into weather and weather impact products. In July 2004, two contractors were selected for a fly-off. The JET contract was awarded to Raytheon on 28 Mar 2006, after a 20 month source selection process. Fielding of the first increment is expected to begin in Jan 2007, with an expected delivery of all JET capabilities by FY 2013.

Tactical Decision Aids (TDAs) provide warfighters an automated way to "visualize" environmental impacts on operations. These tools, which continue to be integrated into command and control systems (e.g., mission planning systems), include Target Acquisition Weapon Software (TAWS) (Figure 3-DOD-6 on next page), Infrared Target Scene Simulation (IRTSS), and Tn-Service Integrated Weather Effects Decision Aid (TS-IWEDA). The Air Force Research Laboratory (AFRL), the Navy's Space and Naval Warfare Systems Command, the Navy Research Laboratory (NRL), and the Army Research Laboratory (ARL) are developing these modular programs. TAWS provides a joint mission-planning tool to combine platform, weapon, target, background, and weather impacts to depict three-dimensional target acquisition and lock-on range and recognition range versus time. This includes prediction of environmental impacts on night vision goggles and low light-level systems used by air, naval, and ground forces to execute nighttime operations. IRTSS uses detailed terrain information and multispectral imagery with TAWS weather inputs to generate forecast target scene images for mission rehearsal. The TS-IWEDA uses environmental data with force, mission, and/or individual weapons rules of engagement or performance parameters to automatically generate mission-impact forecasts for large-scale planning efforts such as Air Tasking Order preparation. TAWS, IRTSS, and TSI-WEDA integrate environmental impacts into the mission execution forecasts for C2 and MP systems throughout the military planning and

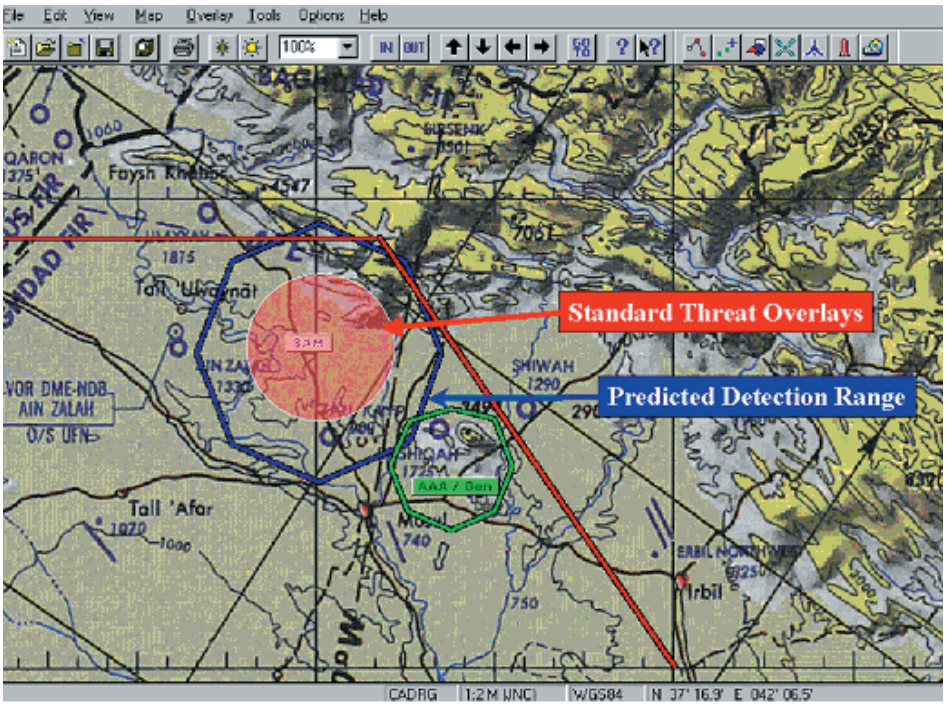


Figure 3-DOD-6. Target Acquisition Weapon Software (TAWS) integrate meteorological conditions and environmental parameters to enhance the mission planning process and increase aircrew situational awareness for mission execution.

execution cycle. The TDA program continues adding weapons systems and targets at the request of users from the Services. Additional decision aids in development or in coordination include the Airborne Laser (ABL) Atmospheric Decision Aid (ADA) to support ABL development and operations and a common radio frequency (RF) system performance prediction capability based on U.S. Navy software.

AFWA's Special Support Operations Branch (SSOB) generates a myriad of products ranging from air refueling forecasts, to detailed mission control forecasts, to weather impacts for SOF operations, and distributes this information via secure media to support worldwide Joint SOF operations. The branch also provides tailored meteorological information for end-to-end planning at U.S. Special Operations Command (USSOCOM), Service component special operations commands, and theater special operations commands. The SSOB is continually involved in global military operations, including Operations ENDURING FREEDOM and IRAQI FREEDOM. Additionally, the SSOB includes the American Forces Network Weather Center, which provides worldwide, broadcast-quality public weather services and planning forecasts through the American Forces Radio and Television Service to over 1,000,000 Department of Defense (DOD) and Department of State personnel and family members stationed overseas.

AFWA's IC Weather Branch provides detailed global cloud analyses and forecasts to the intelligence community. The branch provides worldwide mission-tailored planning and execution forecasts for IC agencies at security levels up to Top Secret/Sensitive Compartmented Information (TS/SCI). The branch also serves as the focal point for AFWA Special Access Program (SAP) requirements; ensures the IC and other SCI and SAP meteorological requirements are integrated into AFWA programs; monitors and evaluates accuracy and timeliness of centralized weather services to the IC, and interfaces with the DOD and IC regarding weather services and the exploitation of weather information.

As the sole source of DOD space

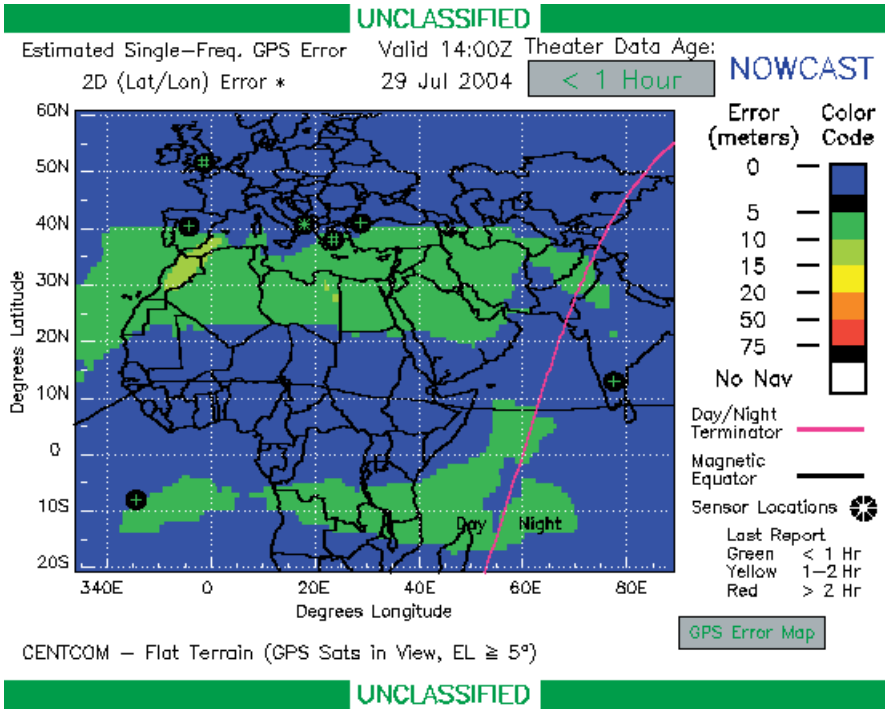


Figure 3-DOD-7. Single-Frequency GPS Receiver Error Map (visualized by HQ AFWA)

environmental information, AFWA partners with NOAA's Space Environment Center to meet the nation's military and civilian space weather needs. AFWA's Space Weather Branch provides a suite of automated and manually tailored analyses and forecasts (including advisories and warnings) of space weather phenomena that affect military operations and IC activities. Similarly, signal fades due to space weather effects on UHF satellite communications (SATCOM) links provide valuable planning information to improve command and control capabilities. Further examples of model output informational products include Single-Frequency GPS Receiver Error maps (Figure 3-DOD-7 on previous page), UHF Satellite Communication Scintillation maps (Figure 3-DOD-8), HF Illumination maps (Figure 3-DOD-9), and Radar Auroral Clutter maps. These products assist warfighters in determining and mitigating space weather impacts to their systems as well as in exploiting enemy space weather susceptibilities for possible asymmetric advantage.

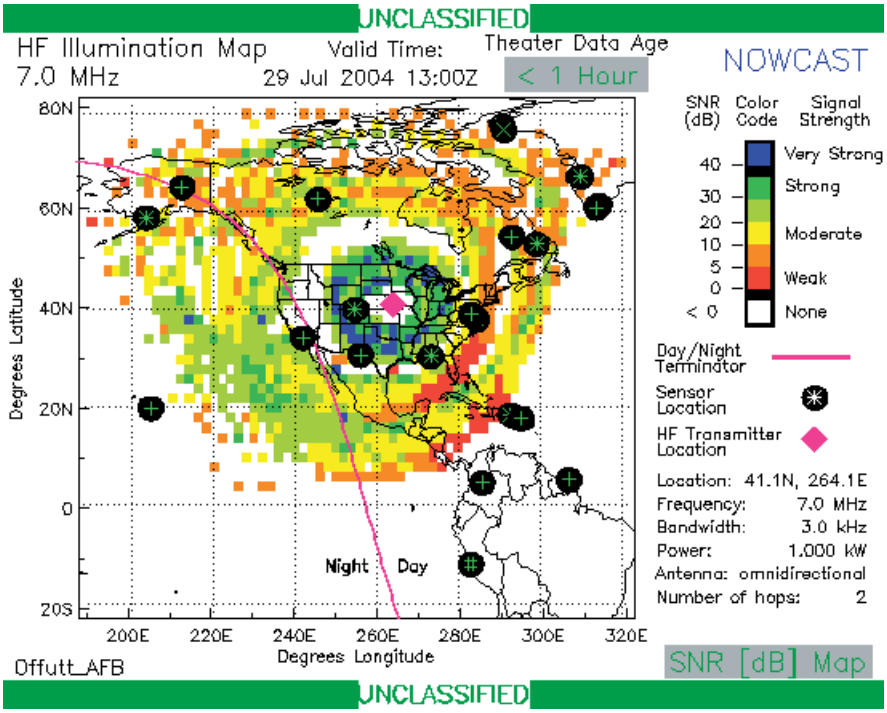


Figure 3-DOD-9. HF Illumination Map (visualized by HQ AFWA).

The AF provides meteorological and space weather products to the nation's space and missile programs, including a wide range of weather observing services at the AF Eastern Range and the Kennedy Space Center (KSC). The AF also provides tailored forecasting for NASA's manned and unmanned launches and for commercial launches from KSC. In addition, the AF provides specialized meteorological information for the AF Western Range at Vandenberg AFB, California; the Pacific Missile Range, which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii; White Sands Missile Range, New Mexico; Kwajalein Missile Range, Republic of the Marshall Islands; and other DOD research and test facilities as directed.

The AF also provides agro-meteorological support to the U.S. Department of Agriculture's Foreign Agricultural Service and other similar users. The output includes diagnostic soil hydrology and other meteorological information pertinent to crop growth and yield estimation as well as to trafficability and rudimentary flooding estimations.

Integration. Tailored environmental information and operational impacts are of little use to decision-makers if

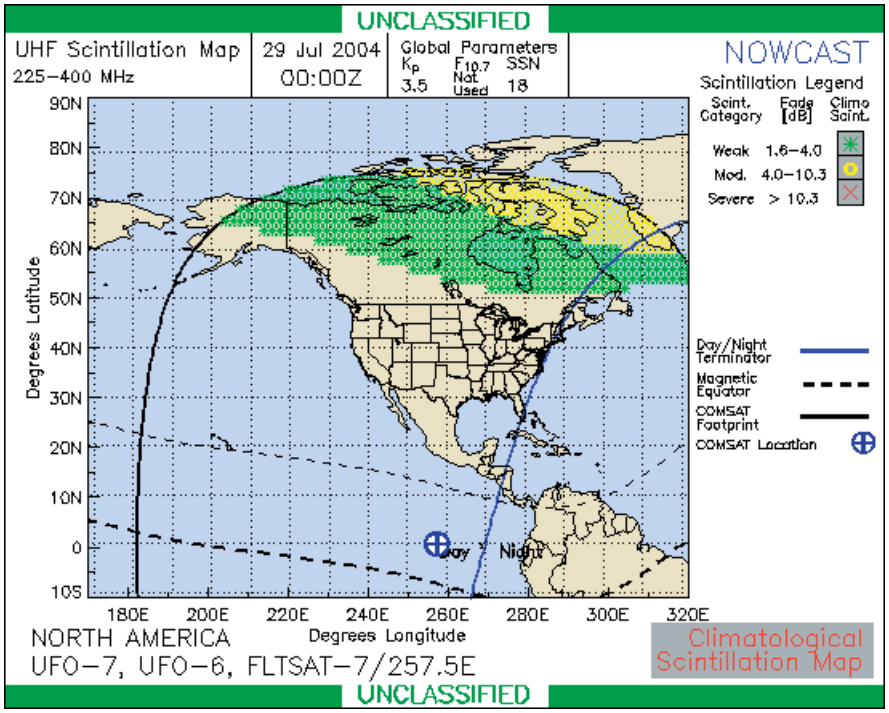


Figure 3-DOD-8. UHF Satellite Communications Scintillation Map (visualization by HQ AFWA)

the information/impacts are not integrated into the shaping, planning, execution, and sustainment of air, space and land operations. The AF employs a blend of information technology (IT), including automated machine-to-machine interfaces, and personnel embedded at the right echelons with decision-makers, to integrate accurate, relevant, and consistent weather and weather impacts information into decision-making processes. Since timeliness is critical to effective integration; AFW operations rely on robust, assured communications for dissemination.

AFWA receives alphanumeric weather data, parses it according to data type, eliminates duplicate reports from different sources, and creates specially tailored bulletins. Some of these bulletins are sent to the large processing centers to provide the input data for global, regional, and fine-scale forecast models. Other bulletins are redistributed to end-users over dedicated circuits, NIPRNET, and satellite broadcast facilities.

High-speed communications between large DOD and civilian processing centers facilitate sharing of data, high-resolution satellite imagery, and output from numerical weather prediction models. Additional circuits provide a subset of these data to OWSs.

Forecaster-developed products and gridded data sets are distributed from AFWA via the Weather Product Management and Distribution System to base/post-level weather forces around the globe using the DOD's Non-Secure Internet Protocol Router Network (NIPRNET) and Secure Internet Protocol Router Network (SIPRNET). Alphanumeric data, including surface, upper-air, space weather, and pilot reports, are also collected and distributed via the Automated Weather Network (AWN), Very Small Aperture Terminal (VSAT) satellite communications system, and the NIPRNET. The AWN, consisting of data collection, message creation, and dissemination software, is a global communications network used for alphanumeric terrestrial and space weather data. The AWN supports DOD as well as federal and foreign meteorological, space, and aviation centers.

AFWA operates a website on the NIPRNET known as the Joint Air Force-Army Weather Information Network (JAAWIN). JAAWIN provides worldwide access to numerical model forecasts, satellite imagery, forecaster-in-the-loop (FITL) products, and text bulletins, and includes links to all OWS websites. Additional products are available to classified users via JAAWIN-Secret (JAAWIN-S) and JAAWIN-Sensitive Compartmented Information (JAAWINSCI).

JWIS offers another means of making tailored weather information available to DOD users. JWIS provides a link to weather information from both AF and Navy sources for exploitation by command and control systems and applications. AFW successfully demonstrated a JWIS-based machine-to-machine (M2M) weather information transfer to command and control applications during Joint Expeditionary Force Experiment 2004.

Although information technology continues to enhance the integration of weather and weather impact information into decision-making processes, well-trained weather professionals are still essential. Designated AFW personnel serve on the staffs of operational AF, Army, and Joint force units worldwide. In this capacity, they identify weather-sensitive areas of the operation and provide expert advice to help mitigate weather impacts on personnel, platforms. weapons and weapons systems, and tactics. The ultimate goal is to identify opportunities for an asymmetric advantage over our foes, i.e., when enemy force capabilities are more severely degraded by weather than those of friendly forces.

For AF operations, these weather professionals are normally assigned to a flight under an operations support squadron in a flying wing; however, individuals from the weather flight are integrated into flying squadron mission planning and execution processes. In this capacity, they infuse critical weather information at key points in the decision cycle to help aircrews maximize wartime capabilities, enhance flight safety, and optimize training effectiveness. Weather experts are also assigned to weather specialty teams (WST) in air and space operations centers (AOCs). This cross-cutting team integrates all-source actionable environmental information at key decision points of air and space operations planning, execution, and assessment. Armed with this information, decision-makers can balance operational risks against mission need to optimize timing, tactics, target and weapons selection, and other factors affecting air and space operations. Finally, AFW experts are integrated into a variety of other unique mission areas, such as space launch support and research, development, test, and evaluation (RDTE) activities. In each capacity, these specialists enable the supported organization to minimize or alleviate weather impacts to the mission. For instance, to avoid potentially devastating storms, space launch weather personnel may advise decision-makers to adjust launch timing, while RDTE weather personnel may identify potential weather sensitivities to system developers to ensure a safe, effective design.

Likewise, Army weather requirements are incorporated into the AF's overall weather operations concept. AFW forces are integrated with Army intelligence staffs, and the Army trains and educates AF personnel on Army organizations, concepts of operations, and their weather sensitivities. AFW forces are currently aligned with echelons above corps, corps, divisions, sep-

arate brigades, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). Over the next few years, AFW support to the Army will undergo significant transformation as the Army transitions from a division-centric force based on large standing organizations to a brigade-centric force based on smaller, modular organizations.

The emerging operational environment (post-Cold War, 9-1l, and Global War on Terror) is characterized by less predictability stemming from decentralized, well-networked threats. The AF is transforming the way it delivers environmental information to the warfighter to meet these challenges. Key to this transformation is creating an information advantage through the robust networking of well-informed, geographically dispersed forces, which will help create a decisive warfighting advantage. In this fast-paced, net-centric environment, the AF will rely more heavily on machine-to-machine (M2M) information exchanges. The challenge to AFW forces is to deliver timely and actionable information via M2M exchanges, thereby supporting more efficient and faster application of force on shorter decision timescales.

In 2001, AFWA initiated the WDAC program to begin the migration to the DOD Joint METOC Data Architecture to support dynamic, fast-paced M2M operations. This architecture provides for authoritative, timely, accurate, and relevant environmental information, accessible via a common web-services interface from anywhere on the Global Information Grid (GIG). The WDAC program modernizes the AFWA production center and AFCCC infrastructure, providing a centralized net-centric reach-back source for worldwide space and atmospheric weather information, to include environmental intelligence data to C2, C4ISR, MP, and mission support systems such as the Joint Mission Planning System. This vision is accomplished through implementation of the Joint METOC Data Base (JMDB), which is a virtual collection of worldwide METOC databases. JMBL is the common mechanism for users to access the JMDB for M2M operations.

Increments one and two of WDAC delivered JMGRID (gridded analysis and forecast data), JMOBS (conventional observation data), JMAN (alphanumeric messages and bulletins), and JMPLAT (fixed and mobile weather station platform data). In 2006, increment three will deliver JMCAT (weather data catalog) and Gridded CDC (subscription capability for data from JMGRID). For FY 2007, work is underway to develop JMSESS (space environment and solar data), JMIM Lite (imagery and visualized products), and a CDC capability for alphanumeric data. Later increments will deliver JMSAT (METSAT data), JMCLIM (climatology products), and JMR-SOB (remote-sensed observations).

RESEARCH INITIATIVES

The overarching objective of the AF meteorological and space environmental research and development (R&D) program is to provide capability designers, operational weather personnel, and weather information users with the technology and tools to gain and maintain the advantage over a potential adversary. Documented R&D requirements in the atmospheric sciences are articulated in the AFW Mission Support Plan and in the Mission Area Plans of the AF major commands. Space environment R&D is targeted to meet the DOD's space weather requirements as documented in the AFW and AFWA Strategic Plans, the AFW Characterize the Environment Enabling Concept, and the AFW Space Weather Modeling Implementation Plan. AFW also strives toward improvements through cooperative research and development agreements with for-profit companies. AFW has recently fielded an IOC version of the Utah State University (USU) developed Global Assimilation of Ionospheric Measurements (GAIM) model. AFW continues to work with USU toward the fielding of a full physics version of the GAIM model sometime in FY 2008-2009. In addition, AFW will be working during FY 2007 to fully integrate ultraviolet sensing instruments (SSUSI, SSULI, and GUVI) into space weather operations. This effort will include model integration, visualization, and validation efforts.

In meteorological R&D, the AF is improving cloud depiction and forecasting system (CDFS) techniques by doubling the resolution, integrating geosynchronous METSATs into the cloud analysis, using a new cloud interpretation scheme, and blending numerical weather prediction with forecast cloud advection techniques. The AF has transitioned key advances in tactical decision aids into operations, permitting improved forecasting of electro-optical system performance and generation of cloud and target scene visualizations for training, system development, and mission rehearsal. In addition to internal efforts, AFW will continue to rely on collaboration and leveraging of efforts with other federal meteorological agencies, research labs, and universities to further improve CDFS system performance and meet other research needs.

Mesoscale Modeling for AF and Army Operations

The Weather Research and Forecasting (WRF) model is the next generation community model expected to replace MM5. It is another area of AFWA participation in research. AFWA is closely collaborating with the National Center for Atmospheric Research (NCAR), NOAA's NCEP, NOAA' s Earth Systems Research Lab-

oratory (ESRL), the University of Oklahoma's Center for the Analysis and Prediction of Storms, and others in WRF development. AFWA is preparing to initially implement WRF operationally in 2005, and will continue with sponsorship and funding of development at NCAR and ESRL, test and evaluation of real-time runs of the WRF prototype, and will lead the Land Surface Model (LSM) Working Group while participating in others. The LSM analyzes the current state of the land surface to provide information to both DOD and civilian agencies, and through coupling with WRF, will improve forecasting performance in the low levels of the atmosphere. This allows AFW forces to provide better forecasts for low-level aircraft operations, the dispersion of aerosol contaminants, and the employment of precision-guided munitions. It also allows for assessment of trafficability for ground forces.

Through a joint AF-Navy effort, AFWA and FNMOC were awarded a $4.2 million grant from the DOD High Performance Computing Modernization Office in 2004, to establish an operational test and evaluation center for the WRF modeling framework. Additionally, each organization gained status as a DOD High Performance Computing Distributed Center. The WRF Operational Test Center (OTC) will greatly enhance DOD's ability to efficiently incorporate state-of-the-science modeling technologies into operations. The end result will be never-before-seen predictive accuracy of fine-scale weather features crucial to DOD operations. A cutting-edge IBM supercomputer suite, split into two identical subsystems, was installed at each weather center. The distributed WRF OTC subsystems will be virtually integrated using high-speed communications networks, allowing operational simulations with real-time weather data from each center. After rigorous test and evaluation, the specialized WRF configurations that perform optimally for DOD and Service-unique mission needs will be implemented at AFWA.

Over the next several years, AFWA will transform its mesoscale modeling approach from a traditional deterministic (single forecast) process to a stochastic (multiple forecast) process with the use of ensemble forecasting (EF). The purpose of this change is to add forecast uncertainty information into weather support, thus enabling optimal decision making for warfighter Operational Risk Management (ORM). AFWA is currently exploring how to best design and apply EF to weather operations with a prototype project called the Joint Ensemble Forecast System (JEFS). Dependent on the success of JEFS, AFWA will begin operational transition of EF in 2008.

Atmospheric Optical Turbulence

Electro-optical (EO) systems are adversely affected by optical distortions caused by thermal or refractive turbulence. As the sophistication of current and next-generation military systems grows, the requirement for more detailed knowledge of fine-scale (meters or less) atmospheric behavior also grows. The Airborne Laser (ABL) program is one such capability whose performance is highly dependent on the variations of the meteorological conditions that produce optical turbulence. The AF program in atmospheric optical turbulence measurements and modeling seeks to address these needs. Researchers used a balloon-borne turbulence sensor mated to a standard radiosonde to obtain measurements, producing data and empirical models that are the basis for ABL system specification. Balloon-borne measurements were made in conjunction with airborne stellar scintillometer measurements to understand the relation between atmospheric structure and path-integrated optical effects. The turbulent scalar spectrum was also sampled using balloon-borne high-bandwidth sensors. As part of an international program, aircraft measurements of temperature and velocity turbulence have been made in different locales worldwide. Horizontal measurements by the aircraft augment the vertical profiling by balloons to assist in the development of the detailed knowledge required to support new EO systems.

United States Weather Research Program (USWRP)

USWRP's mission is to accelerate forecast improvements for high-impact weather phenomena and to facilitate full use of advanced weather information. AFW first entered into discussions with USWRP in 2001, to explore expanded participation in the program. The program currently focuses on land-falling hurricanes, heavy precipitation, and socio-economic impacts. The AF is eager to leverage future efforts in the areas of observing, assimilation strategies for data-sparse regions, and urban forecasting to increase warfighters' abilities to anticipate and exploit the weather. AFW is already committed to the USWRP-affiliated community development of the WRF model and will continue its USWRP involvement during the coming fiscal year.

Air Force Research Laboratory (AFRL)

AFRL supports AFWA by executing research conducted by external agencies and by conducting in-house research on both terrestrial and space weather. AFRL works with AFWA to execute the research portion of AFWA's forecasting and modeling program. AFRL coordinates with government agencies (e.g. NASA), Federally Funded Research and Development Centers (e.g. NCAR), and private corporations to fund research in support of weather model development.

AFRL's in-house terrestrial weather program concentrates on optical turbulence. This research attempts to determine the impact of optical turbulence

on laser propagation. Basic mechanisms of turbulence genesis, energy transfer, and dissipation are explored. Methods are explored for predicting the impact of turbulence on laser propagation with an emphasis on developing forecasting methods. Research is also being performed on determining the impact of cloud layers on directed energy transfer. Emphasis is on detecting and predicting cloud layers that interfere with lasers.

In space weather research, AFRL programs focus on ionospheric impacts to radio frequency systems, space particle specification and forecasts, solar disturbance prediction, and neutral density effects on Low-Earth Orbit (LEO) spacecraft. Working closely with the DMSP System Program Office (SPO) at the Space and Missile Systems Center (SMC) under a Memorandum of Agreement, AFRL supports the development and upgrading of operational space weather sensors, models, and software products to include: space environment sensors on the DMSP spacecraft; state-of-the-art ground-based scintillation detectors; total electron content sensors; DISS; SEON; and the Operationalized Space Environment Network Display suite of web-based products.

In addition to the AFRL research portfolio, AFW collaborates with others in the space weather community to develop new techniques, models, and systems for transition to operational applications. These include the Community Coordinated Modeling Center (CCMC), John Hopkins Applied Physics Laboratory, the Naval Research Laboratory, NASA, NOAA's Space Environment Center, and the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC).

In conclusion, through a continuous process of review and definition, the AF documents its requirements for research aimed ultimately at providing timely, accurate, relevant, and consistent weather information to the warfighter today and in the future. In meteorological R&D, AFW is committed to continued development of the WRF model and collaboration with others to the benefit of the warfighter and the nation. Space weather research will continue with a strong program at the AFRL to facilitate the transition of required capabilities to operational use at minimum expense.

METEOROLOGICAL SERVICES

The United States Navy Oceanography Community (officer and enlisted personnel) are required to assess both meteorological and oceanographic (METOC) impacts on naval, joint, and combined operations. METOC support begins with intelligence preparation of the environment (IPE), or measuring the physical environment, and culminates with exploitation of the environment by employing sensors and weapons in a manner that result in more effective force protection and offensive strike operations. The generation of METOC forecasts and determination of potential environmental impacts on platforms, sensors, and weapons systems requires the collection of METOC data through a variety of tactical and dedicated sensors (including satellites), the fusion and analysis of atmospheric and oceanographic conditions, and the integration of METOC knowledge into decision aids/mission planning systems.

The Office of the Oceanographer/Navigator of the Navy was recently realigned under the Chief of Naval Operations (CNO), Integration of Capabilities and Resources (N8) and CNO, Warfare Integration (N8F), and is now designated as CNO (N84). The Commander, Naval Meteorology and Oceanography Command (COMNAVMETOCCOM), is an Echelon III command and reports directly to the Commander, U.S. Fleet Forces Command (COMUSFLTFORCOM) for meteorological and oceanographic (METOC) operational support. While operational requirements are coordinated through COMUSFLTFORCOM, the CNO, through the Office of the Oceanographer of the Navy (N84), sponsors the development of future capabilities with related research and development (R&D) and acquisition to support prioritized requirements. The Navy METOC organization provides meteorological support services for Navy and joint forces, meteorological products to the uniformed services and other Government agencies, and oceanographic support to all elements of DOD.

Research and development is conducted by warfare centers, laboratories, and systems commands, through sponsorship by the Chief of Naval Research and the Oceanographer/ Navigator of the Navy. To ensure that all research and development supported by the Oceanographer is in direct support of the Naval Mission as established by formal Navy Doctrine, the Oceanographer has developed and implemented a comprehensive framework to transition research to operations. The Naval Research Laboratory (NRL) and the Program Executive Office (PEO), C41 and Space are the primary activities that manage naval research and transition to operations, and are supplemented by various universities, industry partners, and organizations under Navy contract. NRL detachments are collocated with the Fleet Numerical Meteorology and Oceanography Center in Monterey, California and with the Naval Oceanographic Office at Stennis Space Center, Mississippi. The PEO C41 and Space Program Office (PMW-l80) is Navy's single program manager for METOC system development and acquisition. The Naval Oceanography Community is moving towards increased automation and more "machine to machine (M2M)" operations using a service oriented architecture and web-based services in the future.

In 2006, the Naval Meteorology and Oceanography Command continued its realignment and transformation from a geo-centric to knowledge-centric organization designed to directly and measurably enhance warfighting capabilities.

Major Activities within the Command currently include:

- Naval Oceanography Operations Command, Stennis Space Center, MS,
- Naval Oceanographic Office, Stennis Space Center, MS,
- Fleet Numerical Meteorology and Oceanography Center, Monterey, CA,

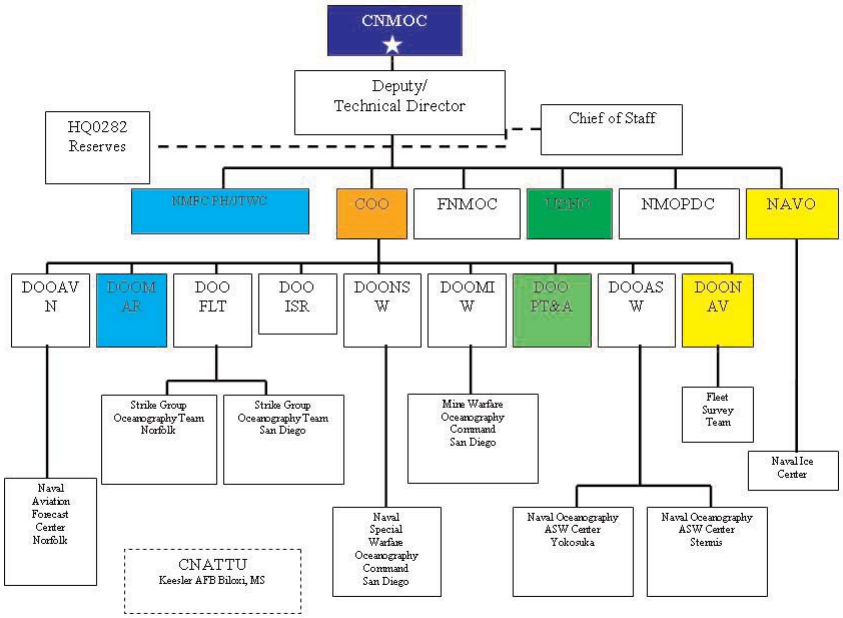


Figure 3-DOD-10. Naval Meteorology and Oceanography Organization. (COO - Commander, Oceanography Operations and DOO - Director, Oceanography Operations)

• Naval Maritime Forecast Center/ Joint Typhoon Warning Center, Pearl Harbor, HI,

• U.S. Naval Observatory, Washington, DC, and

• Naval Meteorology and Oceanography Professional Development Center, Gulfport, MS.

Additional subordinate commands include:

• The Naval Aviation Forecast Center, Norfolk, VA,

• Strike Group Oceanography Teams in Norfolk, VA and San Diego, CA,

• Mine Warfare Oceanography Command, San Diego, CA,

• Naval Special Warfare Oceanography Center in San Diego, CA,

• Naval Oceanography ASW Centers in Yokosuka, Japan and Stennis Space Center, MS,

• Fleet Survey Team, Stennis Space Center MS, and

• Naval Ice Center, Suitland, MD.

NAVAL OCEANOGRAPHY OPERATIONS COMMAND

The Naval Oceanography Operations Command (NAVOCEANOPSCOM), Stennis Space Center, MS, was established in early 2006, as an Echelon IV command reporting to Commander, Naval Meteorology and Oceanography Command. The NAVOCEANOPSCOM, headed by the Commander, Oceanographic Operations, serves as the principal operational organization of CNMOC and coordinates and manages efforts among field activities under the Operational Oceanography Program to optimize warfighting resources, support safe operations and enhance dominance of the battlespace through superior understanding and exploitation of the environment.

NAVOCEANOPSCOM encompasses nine separate directorates:

• Anti-Submarine Warfare (ASW);

• Mine Warfare (MIW);

• Naval Special Warfare (NSW);

Figure 3-DOD-11. Forecasters at the Naval Maritime Forecast Activity (NMFA) Norfolk monitor current weather conditions within the SECOND FLEET area of responsibility. The Naval Meteorological Center is currently preparing for the upcoming hurricane season predicted to be as or more severe than last year. (U.S. Navy Released)

• Navigation (NAV);

• Precise Time and Astronomy (PTA);

• Intelligence, Surveillance and Reconnaissance (ISR);

• Maritime (MAR) Operations;

• Fleet (FLT) Operations (Strike and Expeditionary); and

• Aviation (AVN) Operations.

The Commander, Oceanography Operations supports the combatant commanders and national missions, U.S. interagency and international partners. The other NAVMETOCCOM production centers (NAVOCEANO, FLENUMETOCCEN, NMPOC/JTWC, etc.) support the Commander, Oceanographic Operations.

The command's operational model is based on standardizing services for each directorate, automating everything that can be automated, and coupling situational awareness and a small on scene presence, supported by a significant 24/7 reachback production capability at the major production centers. Aviation and maritime operations have also been centralized and are now organized under the aviation and maritime directorates of the NAVOCEANOPSCOM.

Aviation Forecasting

Aviation forecasting is now conducted at CONUS and OCONUS aviation forecasting hubs which provide flight route weather briefings, point weather warnings for Navy airfields, Terminal Aerodrome Forecasts provided every 6 hours and Forecast advisories for aircraft. Forecasting for the Atlantic is conducted by the Naval Aviation Forecast Center in Norfolk, VA. A Naval Aviation Forecast Component will also be established in San Diego, CA to provide aviation meteorology products to military assets. Routine aviation and installation weather for NATO and the U.S. European AOR is provided by the Naval Aviation Forecast Activity (NAFC)/21st Operational Weather Squadron in Sembach, Germany.

Systems used in aviation forecasting include:

• Flight Weather Briefer, a DOD-developed automated web-based system used to request, produce and disseminate flight route weather briefings.

• Leading Environmental Analysis and Display System (LEADS) Avia-

tion Forecasting System. The primary display and analysis tool used by our forecasters.

• Automated Surface Observing System (ASOS). The Navy's primary airfield environmental observing system, standardized with Federal Aviation Administration and National Weather Service.

Fleet Operations

The Naval Meteorology and Oceanography Command is actively engaged with Fleet forces to provide valuable environmental knowledge to aid warfighting decision making. Skilled personnel are integrated with the Fleet, where they provide in situ observations, run tactical decision aids and interpret environmental data to provide decision support to fleet commanders. The onboard personnel work with reachback cells that refine data, develop models, conduct forecast analyses, and deliver high-quality information to Fleet commands.

Tailored Strike Group Oceanography Team (SGOT) Detachments train, work-up, and deploy with carrier and expeditionary strike groups through each face of the FRTP and deployment. Each SOOT Detachment includes a trained cadre of meteorologists and oceanographers who forecast for the CVNs/LHDs/LHAs. In addition to flight deck weather, they forecast the target area METOC that varies greatly considering the tremendous reach of Naval Aviation along the world's dynamic coastlines. Naval Strike Group Oceanography Teams are located in Norfolk, VA, and San Diego, CA. Support in the European AOR is provided by the Naval Strike Group Oceanography Team, collocated with Naval Aviation Forecast Center in Norfolk, VA.

US Marine Corps landing forces receive METOC support from Marine METOC Support teams and METOC divisions on amphibious capable ships.

Maritime Operations

The Maritime Directorate is located at the Naval Maritime Forecast Center in Pearl Harbor, HI. There is also a Naval Maritime Forecast Activity (NMFA) collocated with the Naval Aviation Forecast Center in Norfolk, VA. NMFA Norfolk supports Optimum Track Ship Routing and en route weather for the Atlantic, Mediterranean, waters surrounding Western and Southern Africa, and the Black and Baltic Seas.

Key components of the maritime operations mission are ship routing, forecasts and warnings and support for ice operations. Significant contributions to maritime safety and efficiency include:

• Optimum Track Ship Routing (OTSR), an enroute weather forecasting service to support trans-oceanic transits and coastal operations of the Navy and naval support ships. OTSR services also include sortie recommendations for potentially damaging weather conditions in port. Additionally, OTSR provides climatologic outlooks for preliminary transit and mission planning.

• Delivery of tropical cyclone forecasts, warnings and other products.

• Ship weather forecasts (WEAX).

• Aviation weather forecasts for ship-based helicopters.

• High wind and seas warnings, special weather advisories and local area warnings.

• Ice analysis and forecasting by the National Ice Center, a joint operations of the Naval Ice Center, U.S. Coast Guard and NOAA.

• Joint Operational Area Forecasts for Commanders operating in littoral regions.

Figure 3-DOD-12. The Military Sealift Command (MSC) underway replenishment oiler USNS JOHN ERICSSON (T-AO 194), breaks away from the NIMITZ-class aircraft carrier USS RONALD REAGAN (CVN 76) after a refueling at sea in foggy weather.(U.S. Navy Released)

FLEET NUMERICAL METEOROLOGY AND OCEANOGRAPHY CENTER

The U.S. Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC; see https://www.fnmoc.navy.mil/), an Echelon IV activity reporting to the Commander, Naval Meteorology and Oceanography Command, plays a significant role in the National capability for operational weather and ocean prediction through its operation of sophisticated global and regional meteorological and oceanographic models, extending from the top of the atmosphere .to the bottom of the ocean. Through close collaboration with the Naval Oceanographic Office (NAVOCEANO), FNMOC is a key component in the

Figure 3-DOD-13. An F/A-18F Super Hornet assigned to the "Fighting Vigilantes" of Strike Fighter Squadron One Five One (VFA- 151) launches from the flight deck of the NIMITZ class aircraft carrier USS ABRAHAM LINCOLN (CVN 72) during a snowstorm. (U.S. Navy Released)

Navy's operational weather and ocean prediction program. This program provides information that helps give Naval forces an asymmetric advantage in speed, access and persistence in any combat operation for which they may be called upon. Users of FNMOC's products include all branches of the Department of Defense (DOD), the intelligence community (IC), other government organizations (e.g., National Weather Service), private companies, a number of colleges and universities, and the general public.

FNMOC is well known for its long and productive history of implementing, evaluating, operating, maintaining and improving complex Numerical Weather Prediction (NWP) models specifically to meet the requirements of the U.S. Navy. These requirements include the need for a particularly accurate representation of coastal meteorology and the air-sea heat fluxes and wind stresses required to drive the Navy's ocean models. In support of this need, FNMOC acquires and processes over six million observations per day--creating one of the world's most comprehensive real-time databases of meteorological and oceanographic observations--for real-time fusion and assimilation into its models. In addition, FNMOC is designated as the DOD center for global Numerical Weather Prediction. FNMOC uniquely satisfies the military's requirement for an operational global NWP capability based on software certified to DOD information assurance standards and operated in a secure classified environment protected from outside intrusion by DOD certified firewalls. This requirement is driven by the importance of weather and ocean conditions on modern military operations, the need to utilize classified weather observations to guarantee the very best weather and ocean predictions in theaters of conflict, and the imperative to produce and disseminate weather and ocean products to military decision makers without fear of interruption or compromise as a result of cyber terrorists or cyber warfare.

FNMOC employs four primary models, the Navy Operational Global Atmospheric Prediction System (NOGAPS), the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), the Geophysical Fluid Dynamics - Navy (GFDN) model, and the WaveWatch III model (WW3), along with a number of specialized models and related applications.

NOGAPS is a hydrostatic, global spectral model that drives nearly all other FNMOC models and applications in some fashion, and forms the basis for the FNMOC global Ensemble Forecast System (EFS).

COAMPS is a high-resolution, non-hydrostatic regional model, multiply nested within NOGAPS, that has proven to be particularly valuable for forecasting weather and ocean conditions in highly complex coastal areas.

GFDN is a moving-nest tropical cyclone (TC) model, nested within NOGAPS, that is used to forecast TC tracks globally.

WW3 is a spectral ocean wave model that is employed both globally (driven by NOGAPS) and regionally (driven by COAMPS) in support of a wide variety of naval operations.

Other models support and supplement the main models with predictions of ocean thermal structure, ocean currents and other data. All of the models are configured, scheduled and operated under the central control of FNMOC Operations. COAMPS, however, can also be configured, scheduled and operated remotely by users in the field as an on-demand modeling service. This is done over the Web via the FNMOC Centralized Atmospheric Analysis and Prediction System (CAAPS). In general, FNMOC strives to treat the air-ocean environment as a fully integrated system, from the top of the atmosphere to the bottom of the ocean, placing special emphasis on the air-ocean interface.

FNMOC's complex and robust operational prediction capability is designed to deliver, in conjunction with NAVOCEANO, 7x24x365 support organized along the warfare areas.

For example, some FNMOC prod-

ucts consist of detailed forecasts of wind stresses and heat fluxes to drive very high-resolution ocean models at NAVOCEANO that provide ocean thermal structure and currents in support of anti-submarine and mine warfare operations, or near-shore wind, sea and surf forecasts that directly support Fleet Operations through ship-to-objective maneuver. In many cases, the outputs of the FNMOC models feed directly into applications models, tactical decision aids and other products that provide direct support to various weather-sensitive activities associated with the Business Lines identified above. These include optimum path aircraft routing, optimum track ship routing, issuance of high-winds and high-seas warnings, hurricane/typhoon sortie decisions, covert ingress/egress of Special Operations Forces, ballistic missile targeting, cruise missile launch and targeting, radar performance prediction in support of ship self defense, naval gunfire operations, understanding the threats posed by airborne nuclear/biological/chemical agents, search-and-rescue at sea, and many other activities.

FNMOC also provides a wide-range of meteorological and oceanographic observations and satellite imagery to complement its models and applications products. These include on-demand extracts from its global observational database, a full range of Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave/Imager (SSM/I) products, ERS and QuikScat scatterometer wind products, a comprehensive view of tropical cyclones via the FNMOC TC Web Page, and various experimental satellite products fielded for evaluation in conjunction with the Naval Research Lab (e.g., satellite imagery that enhances the visualization of airborne sand and dust). FNMOC also hosts the USGODAE Monterey Data Server in support of the Global Ocean Data Assimilation Experiment (GODAE). This system serves as a one-stop shop for meteorological and oceanographic data and model products required to support global ocean modeling R&D. It also functions as one of two Argo Global Data Assembly Centers (GDACs), hosting the complete collection of quality-controlled Argo temperature/salinity profiling float data.

Many of FNMOC's products are distributed to users over the Web via the PC-based METCAST system, and subsequently displayed and manipulated on the user's PC with the Joint METOC Viewer (JMV) software. This includes all standard meteorological and oceanographic fields, synoptic observations, and satellite imagery. For those who require only graphical display of model-predicted meteorological or oceanographic fields, FNMOC provides a Web-based capability called MyWxMap (i.e., "My Weather Map"). MyWxMap, requiring only a Web browser for access, allows the user to select and quickly display predicted meteorological and oceanographic fields for any user-defined geographical area.

All of FNMOC's production capabilities are fielded on a collection of computer hardware and software designated as the Primary Oceanographic Prediction System (POPS). POPS is organized into two subsystems: the Analysis and Modeling Subsystem (AMS) and the Applications, Transactions, and Observations Subsystem (ATOS). AMS is a cluster of SGI and IBM supercomputers on which the major NWP models run. ATOS is a large suite of IBM Linux clusters that ingests, decodes and quality-controls data; does satellite data processing; hosts many of the applications models and products mentioned above; and supports data distribution via a services oriented architecture and Web portal. Note that FNMOC also hosts a DOD High Performance Computing Modernization Program (HPCMP) Distributed Center, which are integrated closely with POPS.

In addition to its primary role of focused support to the warfighter, FNMOC also plays a key role in the U.S. national program for weather prediction. In this regard, FNMOC's tropical cyclone track predictions, widely recognized as among the best in the world, have proven to be especially valuable, with the National Hurricane Center (NHC) relying on them heavily. FNMOC also provides an important and physically separate backup for some of the models run at the National Weather Service's National Centers for Environmental Prediction (NCEP). In addition, FNMOC serves as the Alternate Joint Typhoon Warning Center (AJTWC), providing the backup for the JTWC located in Pearl Harbor, Hawaii. And finally, FNMOC makes a subset of its products available to the general public via the Internet.

FNMOC benefits greatly from collocation with its supporting R&D activity, the Marine Meteorology Division of the Naval Research Laboratory (NRL/MRY). NRL/MRY is a world-class research organization, with focus on weather-related support to warfighting. FNMOC and NRL/MRY share space, data, software and computer systems, and together with the nearby Naval Postgraduate School represent one of the largest concentrations of weather-related intellectual capital in the nation. Collocation and close cooperation between research and operations, such as exists between NRL/MRY and FNMOC, is the optimum arrangement for transitioning R&D quickly and cost-effectively into new and improved operational weather prediction capabilities.

NAVAL OCEANOGRAPHIC OFFICE

Since atmospheric conditions are inherently coupled to oceanographic conditions, the Navy's program in

meteorology is closely linked with oceanography, which is the focus of the Naval Oceanographic Office (NAVOCEANO) at the Stennis Space Center in Mississippi. NAVOCEANO is an Echelon IV activity reporting to the Commander, Naval Meteorology and Oceanography Command. NAVOCEANO's primary responsibilities include the collection, processing, and distribution of oceanographic, hydrographic, and other geophysical data and products. NAVOCEANO runs and disseminates products from the world's first operational global ocean model - Naval Research Laboratory (NRL) Layered Ocean Model (NLOM) as well as a number of regional and coastal circulation and wave models. NAVOCEANO also runs the Polar Ice Prediction System (PIPS) ice model and provides the output to the National Ice Center for product generation. A key ingredient to ocean model performance is real-time data for assimilation and evaluation. NAVOCEANO is the Navy's primary processing facility for NOAA polar-orbiting satellite data and is nationally recognized for satellite-derived sea-surface temperature and satellite altimeter-derived sea-surface topography and wave height. NAVOCEANO's global sea surface temperature data are critically important to successfully running NOGAPS and COAMPS. Additionally, NAVOCEANO houses a DOD Major Shared Resource Center, enabling transition of the latest research and development models on the most modern scaleable, supercomputing architecture and facilitating transition from R&D to operational use. The NAVOCEANO web site for information is https://www.navo.navy.mil.

NAVAL MARITIME FORECAST CENTER/JOINT TYPHOON WARNING CENTER

Located at Pearl Harbor, Hawaii, the Naval Maritime Forecast Center, an Echelon V activity reporting to the Commander, Naval Meteorology and Oceanography Command, hosts the Command's Maritime Directorate and is collocated with the Joint Typhoon Warning Center (JTWC). The JTWC is the U.S. Department of Defense agency responsible for issuing tropical cyclone warnings for the Pacific and Indian Oceans.

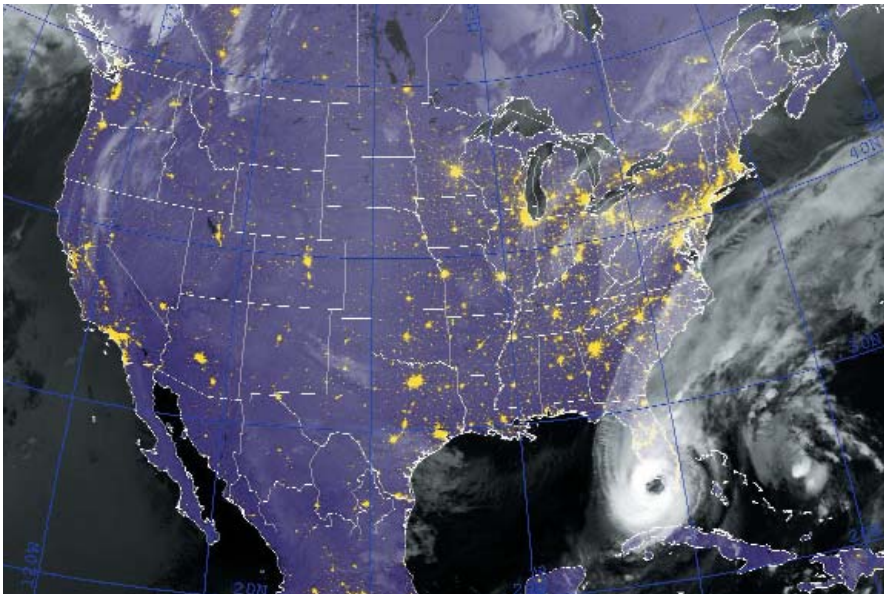


Figure 3-DOD-14. GOES E/W Satellite composite image provided by the U.S. Naval Research Laboratory, Monterey, Calif., showing Hurricane Wilma at 4:00 am EST. Wilma, a dangerous category three hurricane on the Saffir-Simpson Hurricane scale, has maximum sustained winds near 125 mph with higher gusts at this time. (U.S. Navy Released)

Official JTWC support is provided to all branches of the U.S. Department of Defense and other U.S. government departments and their agencies such as the State Department (U.S. Embassies and Consulates), and the Department of Commerce, (U.S. National Weather Service). JTWC products are intended for use by operational units in making decisions regarding ship movements, aircraft sorties and operational planning and by other government agencies in their respective support and international cooperation roles.

As an example, the U.S. National Weather Service, in close cooperation with JTWC, utilizes JTWC tropical cyclone warnings to provide local scale forecasts for the various political entities known as Micronesia. Though not an official member or participant in the United Nations World Meteorological Organization (WMO), JTWC continually attempts to maintain cordial relations with WMO tropical cyclone forecast centers to minimize the issuance of conflicting information. JTWC tropical cyclone warning support is conducted on a 365 days/year, 24 hours/day basis. JTWC monitors, analyzes and forecasts tropical cyclone genesis, development and movement across more than 100 million square miles of the Pacific and Indian Oceans from the west Coast of the Americas to the east Coast of Africa. This area of responsibility encompasses more than 90 percent of the world's tropical cyclone activity.

Manned by U.S. Air Force and Navy personnel, JTWC uses a vast array of data sources and computational resources in fulfillment of the stated mission. These sources include numerous meteorological satellite systems and sensors, radar data, surface and upper level synoptic data and numerical atmospheric models.

U.S. NAVAL OBSERVATORY

The U.S. Naval Observatory in

Washington, D.C., is one of the oldest scientific agencies in the country. Established in 1830 as the Depot of Charts and Instruments, the U.S. Naval Observatory today is the preeminent authority in the areas of Precise Time and Astrometry and distributes Earth Orientation parameters and other astronomical data required for accurate navigation and fundamental astronomy.

The U.S. Naval Observatory serves as the official source of time for the Department of Defense and the standard of time for the U.S.. The atomic clock timescale of the Observatory is based on an ensemble of cesium-beam frequency standards and hydrogen masers.

The U.S. Naval Observatory performs an essential scientific role for the U.S., the Navy and the Department of Defense. Its mission includes determining the positions and motions of the Earth, Sun, Moon, planets, stars, and other celestial objects, providing astronomical data; determining precise time; measuring the Earth's rotation; and maintaining the Master Clock for the U.S.. Observatory astronomers formulate the theories and conduct the relevant research necessary to improve these mission goals. This astronomical and timing data, essential for accurate navigation and the support of communication on Earth and in space, is vital to the Navy and Department of Defense. It is also used extensively by other government agencies and the public at large.

EDUCATION/TRAINING

Navy Oceanography Officers are all university graduates in meteorology, oceanography or other earth sciences, with most attaining dual meteorology and oceanography advanced graduate degrees.

Enlisted forecasters/briefers are trained in meteorological analysis and forecasting at military schools. Enlisted observers receive training at military schools.

The enlisted Aerographer's "A" (observer) and "C" (forecaster) schools are located at the Naval Technical Training Unit collocated with Air Force and Marine weather training at Keesler Air Force Base, Mississippi.

Ongoing professional development for both officer and enlisted personnel is offered through the Naval Meteorology and Oceanography Professional Development Center in Gulfport, MS (with Pacific and Atlantic detachments). The center offers directorate training as well as training on oceanographic knowledge continuum.

UNITED STATES MARINE CORPS (USMC)

The mission of the Marine Corps (Meteorology and Oceanography (METOC) Service is to provide meteorological, oceanographic, and space environmental information, products, and services required to support Marine Corps and other military operations. The Marine Corps METOC support infrastructure is designed to readily deploy and operate in austere expeditionary environments. It is capable of providing sustained, comprehensive, and relevant METOC support to all elements of a Marine Air Ground Task Force (MAGTF), as well as bases and stations of the supporting establishment.

Organization

The Deputy Commandant for Aviation, Headquarters United States Marine Corps (Code ASL37), is the responsible office for Marine Corps METOC requirements and support. The Marine Corps METOC organization consists of two operational chains of command, one for supporting establishment METOC units and the other for the Fleet Marine Force (FMF).

Supporting establishment METOC units are located worldwide at Marine Corp Air Stations (MCAS) and Facilities (MCAF). These activities are manned and equipped to provide direct aviation METOC support and services to host and tenant units at seven major air stations in the continental U.S., one in Hawaii, and two in Japan.

Within the FMF, Marines deploy and employ as scalable, tailored, combined-arms teams known as Marine Air Ground Task Forces. There are three sizes of MAGTFs. They are the Marine Expeditionary Unit (MEU), Marine Expeditionary Brigade (MEB), and Marine Expeditionary Force (MEF) with the latter being the largest. Additionally, Special Purpose MAGTFs (SPMAGTFs) may be formed to support operationally unique situations and/or requirements. All MAGTFs, regardless of size, share four organizational elements that vary in size and composition according to the mission: Command Element (CE), Ground Combat Element (GCE), Aviation Combat Element (ACE), and Combat Service Support Element (CSSE).

FMF METOC activities are organized, trained, and equipped to provide tailored support products and services to all combat elements of the MAGTF. METOC support is focused towards impacts on Expeditionary Maneuver Warfare (EMW) operations, particularly Operational Maneuver from the Sea (OMFTS). FMF METOC activities are fully interoperable within joint force operations as part of a service or functional component command. When directed to stand-up as part of a Joint Task Force Headquarters (JTF HQ), they are capable of planning, coordinating, and leading joint METOC operations. Marine METOC forces can rapidly transition from pre-crisis state to full operational capability in a distant theater to provide on-scene support to MAGTF, combined, joint, allied, and coalition operations and other military operations as may be directed.

FMF METOC assets are permanently assigned to Marine Expeditionary Force Headquarters (MEF HQ), Intelligence Battalions, Marine

Figure 3-DOD- 15. Marines assigned to Weapons Company, 3rd Battalion, 3rd Marine Regiment, conduct a mounted patrol in the cold and snowy weather of the Khowst-Gardez Pass, Afghanistan in order to disrupt any enemy activity. (U.S. Marine Corps Released)

Wing Support Groups (MWSGs), and Marine Wing Support Squadrons (MWSSs). There are three Marine Expeditionary Forces strategically positioned for global response. I MEF, based in southern California and III MEF, forward based in Okinawa, Mainland Japan and Hawaii fall under the control of the Commander, Marine Forces Pacific. II MEF, located at bases in North and South Carolina, falls under the Commander Marine Forces Command. MEF METOC personnel serve as special staff to the Commanding General (CG) and are under the direction and cognizance of the G-2 (Intelligence) Division.

The three Intelligence Battalions in the Marine Corps are co-located with respective Marine Expeditionary Force Headquarters. These battalions directly support the MEF G-2 and serve as MAGTF intelligence centers during operations. METOC is a vital part of the intelligence estimate and is an essential element that supports the Marine Corps Rapid Response Planning Process. METOC personnel assigned to these commands provide expertise, products, and services that directly support the Intelligence Preparation of the Battle-space (IPB) process by helping intelligence analysts to effectively evaluate, integrate, and synchronize METOC effects for both enemy and friendly courses of action.

Marine Aircraft Wings (MAWs) conduct the complete range of air operations in support of the MEF, to include anti-air warfare, offensive air support, assault support, aerial reconnaissance, electronic warfare, and control of aircraft and missiles. The MAW serves as the principle headquarters for the ACE. Most of the MAGTF's METOC support assets reside within the MAW, specifically at the MWSG and its subordinate MWSSs. These assets are organized, structured, and capable of supporting a variety of MAGTF and ACE-specific operations as defined by the size, scope, and mission requirements. Dedicated METOC support is available for all MAGTF elements from within the MAW/ACE.

METOC Support Capabilities

Meteorological Mobile Facility-Replacement (MetMF(R)). The highest level of METOC support to the MAGTF and ACE-specific operations is the deployment of the MetMF(R). The MetMF(R) provides a METOC support capability similar to that found in garrison METOC facilities. The METMF(R) is normally employed as part of MWSS to a Forward Operating Base (FOB) and is the only realistic option for large-scale MAGTF operations. Once established ashore, the MWSS may detach small METOC support teams with portable ancillary equipment to a forward base in support of ACE units that are separated from the main airbase. This redeployment also provides the MetMF(R) with a forward data collection capability that significantly enhances METOC situational awareness and overall support efforts to the entire MAGTF. With appropriate service personnel augmentation, the MetMF(R) is also capable of serving as host for an in theater Joint METOC Forecasting Unit (JMFU) during joint operations and exercises.

METOC Support Team (MST). MSTs are task organized and equipped to provide a limited level of METOC support to combat elements other than the ACE (e.g. CE, GCE, and CSSE) and are assigned in support of MEU operations. It is capable of rapidly deploying as part of a first-in level of METOC support response to a crisis and can be easily integrated into an Air Contingency MAGTF (ACM). Additionally, the MST can be assigned to augment a JMFU during joint operations.

Each MWSS within the MAW is structured and organized to provide one MST that consist of one METOC officer, two forecasters, and two observers. When deployed, the MST will normally be assigned to the G/S-2 (Intelligence) division/section of the supported combat element or MEU. The MST deploys with rugged, ancillary environmental collection and data processing equipment. During operations they organically collect METOC products, data, and information from the nearest deployed MetMF(R), Navy METOC OA Division afloat, host nation or other METOC support organizations and agencies to satisfy

Figure 3-DOD-l6. Marines, supporting Operation Iraqi Freedom with Marine Medium Helicopter Squadron 764, tie down the rotor blades of a CH-46E Sea Knight helicopter as a massive dust storm approaches the squadron's work area in AL ASAD, Iraq. (U.S. Marine Corps Released)

METOC information requirements.

Specialized METOC Support

The Marine Corps' Chemical Biological Incident Response Force (CBIRF) was established in 1996, as a result of Presidential Decision Directive (PDD) 39 to manage the consequences of Nuclear, Biological, and Chemical (NBC) materials or weapons used by terrorists. This national level asset is part of the re-activated 4th Marine Expeditionary Brigade - Anti-Terrorism (MEBAT) located at Indian Head, Maryland. It is comprised of specially trained and equipped Navy, Marine, and civilian personnel who can rapidly be forward deployed and/or respond to a credible threat of a Chemical, Biological, Radiological, Nuclear, or High Yield Explosive (CBRNE) incident in order to assist local, state, or Federal agencies and designated Unified Combatant Commanders in the conduct of consequence management operations. Within the S-2 (Intelligence) section, permanently assigned METOC forecasters provide specialized NBC dispersion forecast products and services that aid mission accomplishment of this organization.

METOC Support Doctrine

Marine Corps War Fighting Publication (MCWP) 3-35.7, MAGTF Meteorological and Oceanographic Support, provides more detailed information about the Marine Corps METOC Service. An electronic copy is available for viewing and downloading from the Marine Corps Combat Development Command (MCCDC), Doctrine Division web site at https://www.doctrine.guantico.usmc.mil/.

ARMY TRANSFORMATION

The United States Army is undergoing a historical transformation from a division-centered Army, to a smaller, brigade based Army. This transformation will require an adjustment on how weather support will be provided to the new modular Army. Weather forces will be pooled at designated Army locations to provide personnel ready to accompany deploying Army forces. These force pools will rely more on "reach back" capabilities to obtain pertinent meteorological data. The Army and AF are working together to determine the optimal weather team sizing, equipment and communications capabilities required to support the new modular Army forces.

OPERATIONAL EQUIPMENT AND SUPPORT MISSIONS

Although it is transforming to a modular force, the existing weather support structure within the U.S. Army is a mix of Army and USAF personnel and equipment according to Army-Air Force agreement (Army Regulation (AR) 115-10/Air Force Joint Instruction (AFJI) 15-157, *Weather Support for the U.S. Army*, 30 June 1996). This joint regulation describes the Service responsibilities and those of Army Commands and Army Service Component Commands (ASCC) within the Army for providing weather support. The U.S. Army provides direct weather support to two Army missions: upper air observations for Field Artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers. AF Major Commands (MAJCOMs) provide operational weather services to war fighting ASCCs in combat, contingencies, and peacetime training. U.S. Army Forces Command (FORSCOM), U.S. Army Europe (USAREUR), U.S. Army Pacific (USARPAC), U.S. Army Special Operations Command (USASOC), Eighth U.S. Army (EUSA), and U.S. Army Training and Doctrine Command (TRADOC) have AF Weather (AFW) personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) Crews provide direct upper air observation support to artillery units in the same ASCC. During peacetime training and activation, the Air National Guard (ANG) provides AF operational weather support to the U.S. Army Reserve (USAR) and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises and contingencies, the ANG may augment the active Army Battlefield Weather forces.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Developmental Test Command's (DTC) Meteorological Teams (MET Teams) and U.S. Army Space and Missile Defense Command (SMDC) contractors. DTC operational support is established under Army Test and Evaluation Command. SMDC provides weather support to the Ronald Reagan Ballistic Missile Defense Test Site at Kwajalein Atoll through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field and communications equipment to USAF weather forces for tactical operations. The Integrated Meteorological System (IMETS) is the U.S. Army's tactical weather communication, intelligence, and information system providing digital weather support to the commanders and staffs of tactical units, from Echelons Above Corps (EAC) to aviation battalions. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to Program Director (PD), IMETS and to Field Artillery meteorology programs.

ARTYMET Crews are assigned to Artillery units at Division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support Field Artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. ARTYMET Crews also take limited surface observations at tactical locations on an "as needed" basis to support artillery operational requirements.

ARTYMET Crews in the Active Component (AC) and RC sections currently use the Meteorological Measuring Set (MMS), AN/TMQ-41, to take upper air observations during tactical operations. It is a mobile, upper air sounding system mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). The MMS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire, to USAF Battlefield Weather Teams (BWTs), and to the Chemical Officer for use in smoke and in Nuclear, Biological and Chemical (NBC) defense operations (Figure 3-DOD-17). The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK, develops requirement documents and is the combat and training developer for meteorological equipment used for Field Artillery support.

Headquarters, Department of the Army, Office of the Deputy Chief of Staff, G-2, is responsible for Army weather support policy. The Office of the Deputy Chief of Staff, G-3, is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements.

ARMY OPERATIONAL SUPPORT PROVIDED BY THE AIR FORCE

Under AR 1 15-l0/AFJI 15-157, the

Figure 3-DOD-17. Accurate wind profiles are essential for the Artillery to engage their targets. Photo courtesy U.S. Army.

AF provides the Army with the necessary manpower and unique tactical and fixed weather equipment to meet Army tactical and garrison active component and reserve component support requirements. Army support manpower requirements are sourced from AF active, reserve, and ANG weather forces. While direct support of the Field Artillery remains an Army responsibility, and is supported by Army ARTYMET teams, AF Battlefield Weather forces provide supplemental information to artillery crews in contingencies for areas beyond direct ARTYMET observation capabilities. The AF assigns AF weather personnel to the war fighting Army Commands and ASCCs at theater, corps, division, armored cavalry regiments, aviation brigades, separate brigades, and Special Forces groups/ranger regiments to provide direct, on site weather support.

AF operational weather squadrons (OWSs) and post-level weather organizations provide garrison and tactical weather warning, observing, forecasting, special support, and staff weather officer (SWO) services to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for aircraft and post resource protection.

Per Army-AF agreement, the AF is responsible for installation, operation, and maintenance of standard AF meteorological and observing equipment at Army Airfields. Tactically, the Army is responsible for vehicles, tactical communications, and weather effects criteria. The Army's IMETS is fielded for these purposes and is operated by AFW personnel. The Army also maintains IMETS hardware and software, with the AF maintaining AF software that performs meteorological functions within IMETS. IMETS uses AF meteorological software, but IMETS is hosted on an Army vehicle, uses Army tactical communications and Army weather effects software. IMETS baseline software is hosted on Army Common Hardware and is Defense Information Infrastructure Common Operating Environment (DIICOE) and Joint Technical Architecture - Army (JTA-A) compliant. The Army provides other tactical equipment to AF BWTs through an Army Table of Organizations and Equipment (TOE). The following paragraphs describe weather activities within Army Commands and Army Service Component Commands.

Eighth U.S. Army

The Eighth United States Army (Eighth Army) requires and uses Army resources to collect upper air data for artillery support. Two artillery meteorological (ARTYMET) crews with the Second Infantry Division (2 ID) use AN/TMQ-41 Meteorological Measuring Sets to collect upper air data for direct use by field artillery units. AFW personnel assigned to the 607th Weather Squadron (607 WS) provide operational weather support to Eighth Army units. The 607 WS provides garrison and tactical weather observing, advisories, mission execution forecasts and staff weather support during armistice operations, exercises and contingencies. These personnel use knowledge of Army missions to prepare theater-scale and site-specific weather forecasts essential to resource protection, operational planning and execution of combat operations. The 607 WS has units at four installations to provide direct support to HQ Eighth Army, HQ 2 ID and the 2nd Combat Aviation Brigade. In FY 2006, the 607 WS had 64 assigned weather personnel to support the Army mission. IAW AR 115-10/AFJI 15-157, the Eighth Army provided garrison facilities, tactical equipment (MTOE and CTA) and an operating budget.

United States Army Europe

United States Army Europe (USAREUR) and 7th Army require and use Army resources to provide meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations.

The Air Force's 7th Weather Squadron (7WS) provides USAREUR/7th Army in-garrison and

Figure 3-DOD-18. Reliable wind forecasts are necessary to ensure safety during airborne operations.(Photo courtesy U.S. Army).

tactical weather intelligence and support. This includes observing services for in-garrison operations, contingency and exercise operations, staff weather officer (SWO) services, and specialized support. The United States Air Forces in Europe (USAFE) Operational Weather Squadron (OWS) at Sembach AB, Germany, provides operational-level forecast products for the European Command Area of Responsibility, to include all USAREUR units. BWTs located at V Corps and its aviation assets, 1st Infantry Division and its aviation brigade,1st Armored Division and its aviation brigade, Southern European Task Force, and 7 Army Training Command, as well as 7WS supporting 7th Army, evaluate and tailor these forecast products to produce mission execution forecasts.

The 7WS mission, with its 10 detachments and operating locations, is to provide weather operations packages to conform to the Army's garrison and war operations. Additionally, 7WS conducts weather operations and planning to meet future Army transformation and modularity initiatives. 7WS will match the deploying weather force structure to the mission that USAREUR is called upon to execute. 7WS will tailor the permanently assigned weather force to meet requirements of the new USAREUR structure and utilize "reachback" capabilities to the maximum extent possible to minimize the fielded footprint without compromising weather operations. During late FY 2006 and early FY 2007, three 7WS detachments will close: Hanau, Giebelstadt, and Wurzburg. These closures follow USAREUR transformation.

Seven IMETS were fielded within USAREUR (V Corps, two divisions and their aviation brigades, and two separate brigades). IMETS is geared to interface as a module of the Army Battlespace Control System (ABCS) to inject weather decision products into the common battle picture for Army commanders. IMETS Light was fielded in Oct FY 2005 to Aviation Brigade weather teams, and an upgrade (version 6.4) was fielded in FY 2005 (Figure 3-DOD-19).

USAREUR provides supporting USAF weather teams with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operating funds (expendables, maintenance, etc.). Four artillery meteorological (ARTYMET) sections collect upper air observations for direct use by field artillery units. The Forward Area Limited Observing Program (FALOP) consists of Army personnel taking lim-

Figure 3-DOD-19. The Integrated Meteorological System - Light (IMETS-L). (Photo courtesy U.S. Army.)

Figure 3-DOD-20. Weather plays an important role in day to day Army operations, such as this bridging operation in South Korea. (Photo courtesy U.S. Army)

ited observations at forward areas in the battlespace. USAREUR G2 funded purchases of handheld weather sensors for use in FALOP training and equipping Army teams to provide limited weather data at Forward Operating Bases and Forward Arming and Refueling Points. These additional "eyes forward" provide critical information that benefits flight safety as well as the theater weather sensing strategy without having to forward deploy more people to austere locations.

U.S. Army Special Operations Command (USASOC)

Weather support to USASOC allows commanders to improve efficiency, effectiveness and safety of operations for USASOC units. Air Force Special Operations Command (AFSOC) and Air National Guard (ANG) weather personnel provide direct support to USASOC units and are assigned to 10th Combat Weather Squadron (CWS); OL-A, 320th Special Tactics Squadron (STS); 321st STS; and OL-A, 353rd Special Operations Group. ANG personnel providing direct support to USASOC when activated are assigned to the 107th MIANG, 146th PAANG, and the 181st TXANG.

SOWT personnel use tactical weather kits to collect limited weather data and provide limited scope meteorological observations from permissive, semi-permissive, and uncertain environments in direct support of Army Special Operations Forces (ARSOF). 10th CWS SOWTs collect weather data at the deployed team level. These observations are passed to operating bases for use by ARSOF commanders and staff and a variety of other weather units and personnel. Specifically, SOWTs provide garrison and tactical support to USASOC units including the U.S. Army Special Forces Command and its seven subordinate Special Forces Groups (SFG); the 75th Ranger Regiment; the 160th Special Operations Aviation Regiment; the United States Army Civil Affairs and Psychological Operations Command (USACAPOC); and all SFG and regimental subordinate battalions and two separate aviation companies. Weather operations include: climatology and solar/lunar illumination tables and studies; courses of action and mission impacts analysis; weather watch/warning services; mission execution forecasts; flight weather briefings; drop/landing zone forecasts; training of ARSOF; training of host nation and indigenous forces on conducting limited observation programs; surface, upper-air and tactical radar observations; and Foreign Internal Defense analysis, surveys, and training. AFSOC SOWTs provide the DOD's sole source for high-fidelity Meteorological and Oceanographic (METOC) intelligence data collection from austere, denied, hostile, or semipermissive areas of the battlespace.

USASOC plans and expends resources for some operational and administrative support to SOWTs providing meteorological service support to USASOC components. USASOC provides funding for office and deployable automation systems and connectivity to local networks; operations and maintenance/sustainment to support USASOC requirements; funding for temporary duty for some USASOC mission needs; and funding for the Army Combat Uniform (ACUs). Additionally, USASOC provides for some tactical items such as NBC and some communications equipment; electrical power, vehicles, life support equipment necessary for accomplishing USASOC weather support missions; and maintenance and supplies for USASOC provided equipment. Fifteen Integrated Meteorological Systems-Light (IMETS-L) have been fielded within USASOC and funding has been secured for thirty-six additional systems. IMETS-L provides AFSOC SOWTs a system to assist with mobile automated weather data receiving, processing, and dissemination. IMETS-L also provides AFSOC SOWTs a system to assist with digital weather support, real-time tailored weather information, forecasts, and weather effects on friendly and hostile weapons systems. USASOC also provides funding for facilities, telephones, office space and

furniture, and real property to house supporting special operations weather units, as well as secure storage of required equipment.

United States Army Pacific (USARPAC)

USARPAC uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating surface weather observations to support tactical units and operations. USARPAC provides supporting USAF units with tactical vehicles, MTOE and Common Table of Allowances (CTA) equipment and operations and maintenance funds. The IMETS and New Tactical Forecast System (NTFS) have been fielded within USARPAC as the primary meteorological equipment for deployed operations. The IMETS and NTFS receive data via Army-provided reachback NTPRNET and SIPRNET conduits. The 25th ASOS weather budget will increase in FY 2007 due to an increase in IMETS funding and the 25ID(L) SWO's operating budget. Approximately $9.4K has been provided for each fielded IMETS-V system, and $ 8.9K for each IMETS-L system. Furthermore, the SWO's operating budget increased from an undeterminably small amount to $25K. The 25th ASOS also supports Bradshaw Army Airfield, for which funding is incorporated into the SWO's operating budget.

The 17th Operational Weather Squadron (17 OWS) at Hickam AFB, HI, provides HQ USARPAC with garrison and tactical weather warnings, forecasts, special support, and Staff Weather Office (SWO) services. Additional BWTs assigned to U.S. Army Japan (USARJ), U.S. Army Hawaii (USARHAW), including the 25th ID (L), and U.S. Army Alaska (USARAK), including 172 SIB, provide direct, on-site support at 5 USARPAC installations. The BWTs also deploy with their customers, providing tailored battlefield observations and forecasts. Weather reengineering has reduced the requirement for forward deployed weather personnel, instead leveraging IMETS and other recently fielded technology for reachback capability. The 17 OWS provides regional weather support, allowing the forward deployed forces to focus on specific area and target forecasts. There are three subordinate commands within USARPAC: United States Army, Hawaii (USARHAW), United States Army, Alaska (USARAK), and United States Army, Japan (USARJ). The 17 OWS provides operational-level forecast products for the USFJ and USFK AORs, to include all USFJ and USFK AF and Army units. This includes specific resource protection support (i.e. weather advisories, warnings, and watches), as well as Terminal Aerodrome Forecasts for selected units. The 5th Air Force (5 AF) Liaison serves as USFJ's Staff Weather Officer (SWO), and also serves as the USARJ SWO. Day-to-day support for Camp Zama, Japan, is provided by an Operating Location (OL) under the AF BWT assigned to the 374th Operational Support Squadron at Yokota AB. The OL on-site at Camp Zama provides observational support and produces mission execution forecasts to support aviation operations.

The 11th Operational Weather Squadron (11 OWS) at Elmendorf AFB AK, provides Operational level forecast products for the Alaskan Command AOR, to include all USARAK units. The Commander, 11 OWS, serves as the CG, USARAK's SWO. Additionally, 11 OWS is responsible for Terminal Aerodrome Forecasts for Fort Wainwright, along with resource protection weather support (i.e. weather advisories, warnings, and watches) for Forts Wainwright, Greely, and Richardson. The 11 OWS provides flight weather briefing support, as required, to Army, Army Reserve, and Army National Guard aviation assets in theater. An AF BWT (3 ASOS/WE) is collocated with the 172d Infantry Brigade (Separate) (172d Stryker Brigade Combat Team (172 SBCT)) at Fort Wainwright, and the aviation assets of 4th Battalion, 123d Aviation Regiment. The 3 ASOS/WE provides weather support for both tactical and garrison operations, observes the atmosphere and evaluates, then tailors, forecast products to produce Mission Execution Forecasts and staff briefings. The 3 ASOS/WE also supports 172 SBCT tactical unmanned aerial vehicle (T-UAV) operations. The Alaska Army National Guard operates the airfield at Fort Richardson.

U.S. Army Forces Command (FORSCOM)

Weather support to the U.S. Army Forces Command (FORSCOM) is diverse and demanding. FORSCOM, the Army's largest major command, requires and uses Army resources to conduct meteorological services in direct support of Army operations. These services include collecting and disseminating upper air observations for artillery support and collecting and disseminating limited surface weather observations to support all tactical units and operations. FORSCOM consists of more than 750,000 Active Army (AA), U.S. Army Reserve (USAR) and Army National Guard (ARNG) soldiers. These soldiers account for more than 80 percent of the Army's combat power. FORSCOM trains, mobilizes, deploys, and sustains combat ready forces capable of responding rapidly to crises worldwide. The AA component of FORSCOM has nearly 200,000 soldiers. Third U.S. Army is the Army component of U.S. Central Command (USCENTCOM), which is the Joint command responsible for Southwest Asia (SWA), the Persian Gulf, and the Horn of Africa. U.S. Army South (USARSO) serves as the Army compo-

nent to U.S. Southern Command (USSOUTHCOM). USARSO relocated from Fort Buchanan, Puerto Rico, to Fort Sam Houston, Texas, in 2003, and became a FORSCOM major subordinate command October 1st, 2003. FORSCOM also commands three Army Corps: I Corps at Fort Lewis, Washington, III Corps at Fort Hood, Texas, and XVIII Airborne Corps at Fort Bragg, North Carolina. Together, they include six divisions, two armored cavalry regiments, five separate brigades and a range of other corps combat, combat support and combat service support units. Two Continental U.S. Armies (CONUSAs), First U.S. Army and Fifth U.S. Army, are responsible for training, mobilization, and deployment support to Reserve Component units in FORSCOM. Another major subordinate command to FORSCOM, the U.S. Army Reserve Command (USARC), commands all U.S. Army Reserve units in the continental U.S. except those assigned to Special Operations Command. FORSCOM's Army Reserve strength stands at approximately 196,000 soldiers. USARC units are part of the Federal force and make their primary contribution to FORSCOM combat power in combat support and combat service support specialties such as medical, civil affairs, transportation, maintenance and supply.

The ARNG provides FORSCOM a balanced force of eight National Guard combat divisions, 15 enhanced separate brigades, extensive combat support, and combat service support units. The current FORSCOM ARNG strength is approximately 367,000 soldiers.

The Army is in a period of transformation, over the next several years where the Army will transform from its current structure to a structure that has two higher headquarters replacing existing divisions, corps and echelons above corps. This transformation is requiring AFW to retune its service approach to Army units in terms of manpower and functions.

Weather support to FORSCOM's AA units comes from dedicated AFW forces aligned under three Air Support Operations Groups (ASOGs) within Air Combat Command (ACC): 1 ASOG at Fort Lewis, Washington; 3 ASOG at Fort Hood, Texas; and 18 ASOG at Pope AFB, North Carolina. A weather squadron under each ASOG supports the Corps. Each Army division normally has dedicated AFW forces aligned under an Air Support Operations Squadron (ASOS) or one of the weather squadrons, at their respective installations. Corps and division weather forces are authorized personnel and equipment to support a variety of missions at the various Army echelons. Weather support at each Army echelon is provided according to Army Field Manual 34-81, and Air Force Joint Pamphlet 15-127. Currently, there are nearly 350 AFW authorizations supporting various echelons across FORSCOM. These personnel, enabled by an operational weather squadron, provide garrison and tactical weather warning, observing, mission execution forecast, special support, and SWO-services during peacetime, combat, contingency, exercise, or armistice operations.

Air Combat Command weather organizations provide direct, on-site support at 11 major, Army installations, including the National Training Center at Fort Irwin, California, and the Joint Readiness Training Center at Fort Polk, Louisiana, and at deployed locations. Support is focused on air, ground, special operations, and other combat and combat support missions.

FORSCOM provides supporting AFW forces with a Modified Table of Organization and Equipment (MTOE) and operating funds (expendables, maintenance, etc.). ARTYMET requirements in FORSCOM increased from 17 to 20 sections in FY 2005, due to modularity. These 6-person sections, comprised of Army weather personnel, collect upper air observations for direct use by field artillery units. Six more teams are planned to be added in FY 2006 - FY 2007.

The New Tactical Forecast System (N-TFS) is the primary in-garrison and tactical weather equipment for receiving graphics and alphanumeric data. Data is received via the Very Small Aperture Terminal (VSAT), Tactical VSAT (T-VSAT), Non-Secure Internet Protocol Router Network, and Secure Internet Protocol Router Network. Nineteen IMETS and 15 IMETS-L, developed by the Army Research Laboratory, have been fielded within FORSCOM. FORSCOM has also fielded commercial Automated Weather Observing Systems at Yakima Training Center, Washington, Fort Campbell, Kentucky, and Georgetown Bahamas.

Training and Doctrine Command (TRADOC)

Headquarters, TRADOC (HQ TRADOC) is responsible for development and management of weather training programs, Army and Joint weather support doctrine (concepts and field manuals), and the establishment of requirement documents for Army tactical weather support. HQ TRADOC is the approval authority for Army-AF weather doctrine, Army weather system requirements, and weather support policy. Key mission areas for the next few years will be to coordinate weather requirements to the Army's Modular Forces; develop new weather support doctrine, concepts, and tactics, techniques, and procedures; ensure weather, weather effects to operations, and weather support processes/procedures are properly trained across the TRADOC schoolhouses.

The IMETS continues as the state of the art Army weather support system. However, over the next few years its capabilities will be consolidated into

the Air Force's Joint Environmental Toolkit (JET) program. The Army will retain research and development efforts related to Army-specific weather support challenges (short-term forecasting in the lowest levels of the atmosphere) and will be responsible for interfacing JET with Army command and command systems. Initial JET fielding is programmed to begin in FY 2007.

The U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH) is the functional proponent for Army tactical weather support. USAIC&FH represents the Army warfighter by collecting weather support requirements and developing solutions to satisfy those requirements. A key component to providing weather support to the Army is IMETS, fielded by the Army and operated by Air Force Battlefield Weather Teams (BWTs). The USAIC&FH Weather Team assists in advising the Army Research Lab, USAIC&FH, DAMI-PO and AFW on Army weather support issues and helps develop solutions to meet both active and reserve forces' weather requirements. In addition, the USAIC&FH Weather Team conducts and monitors initial weather support training to Army Military Intelligence personnel and AFW personnel supporting the Army. The USAIC&FH Weather Team consists of three active duty AFW personnel that support Army concepts, architecture and requirements initiatives; one civilian contractor that manages the Battlefield Weather (BW) course; and one Army Government Civilian that serves as the assistant TRADOC Capabilities Manager (TCM) for IMETS. This year the USAIC&FH Weather Team drafted the initial Army Weather Functional Area Analysis (FAA) and will continue associated work on weather input to the Intelligence, Surveillance and Reconnaissance (ISR) Concept Capabilities Plan (CCP). Also, the team developed a new TRADOC Staff Weather Officer organizational structure which consolidates most SWOs under one office at Ft Huachuca. This new manning initiative includes the future addition of an Army Weather civilian position, also located at Ft Huachuca. Due to personnel turnover, the BW course hired a new Course Administrator this year. The USAIIC&FH TCM for IMETS has coordinated with DCGS-A to ensure the highest level of integration of IMETS as a Program of Record (POR) in the DCGS-A family of systems while developing a clear migration path towards total integration of capabilities. The TCM participated in the DCGS-A Fusion Working Group documenting each intelligence domain's current fusion architecture and documenting the level of automation currently being provided by POR systems for each level of fusion. The TCM also provided DCGS-A an evaluation of IMETS ability to satisfy the DCGS-A CPD requirements. In FY 2008, the IMETS Program Office will move under the Program Executive Office - Intelligence, Electronic Warfare & Sensors (PEO-IEW&S) as part of the Distributed Common Ground System-Army (DCGS-A) program.

The AF SWO at the Army's Combined Arms Center (CAC) is the primary overseer of the Tables of Organization and Equipment (TOE) for BWTs supporting Army operations. The CAC SWO also arranges for or provides environmental data, concepts of operation, and weather subject matter expertise for programs, projects, documents, and studies conducted by the TRADOC System Manager - Army Battle Command System, the Battle Command Battle Lab-Leavenworth, the Center for Army Lessons Learned, the Combined Arms Doctrine Directorate, the TRADOC Assistant Deputy Chief of Staff for Intelligence -Threats, the Foreign Military Studies Office, and the TRADOC Analysis Center-Leavenworth. Other key CAC SWO tasks are to develop weather/weather effects scripts and climatology packages to support modeling and simulation efforts of the Battle Command Training Program (BCTP) and the National Simulation Center, and to make available Army weather support instruction at the Command and General Staff College (CGSC).

The U.S. Army Field Artillery School (USAFAS), Fort Sill, OK is the proponent for upper air meteorological support to the Army. Artillery meteorological crews, Active and Reserve, had used the AN/TMQ-50 to measure surface weather parameters. Tactical reliability issues forced an Army-wide 'STOP-USE' of the AN/TMQ-50 at the end of FY 2003. Artillery meteorological crews currently use manual surface instruments to measure surface weather conditions. The AN/TMQ 55 (TACMET) is being fielded to Artillery Meteorological sections to replace the AN/TMQ 50. The AN/TMQ-41 Meteorological Measuring Set (MMS) and AN/TMQ-52 Meteorological Measuring Set-Profiler (MMS-P) are utilized to take upper air observations. The MMS and MMS-P provides weather data to the Field Artillery Tactical Data System for ballistic calculations; to USAF weather forces for weather forecasting; and to the Chemical Officer for obscurant deployment, and Nuclear, Biological, Chemical (NBC) defense operations. Efforts are ongoing to ensure these surface and upper air observations are sent back to military weather centrals where they can be ingested in to our newest numerical meteorological analysis and forecasting models. Active unit's MMSs will eventually be replaced by the AN/TMQ-52 Meteorological Measuring Set Profiler (MMS-P). The MMS-P is scheduled to begin fielding in early FY 2005. The MMS-P is a suite of meteorological sensors and associated software/models which will provide the Field Artillery with current and/or expected weather condi-

tions at a point where the weapon munitions is expected to engage a target (Target Area Met).

The U.S. Army Engineer School (USAES), Fort Leonard Wood, MO, coordinates weather support requirements for Terrain Analysis and Topographic Engineering. USAES develops methods of measuring and forecasting state of the ground for trafficability assessments using input weather data fields. Their mission also includes identifying, and documenting requirements to interface meteorological and engineer battlefield systems. Due to resource constraints, USAES no longer has a full time civilian meteorologist in the Terrain Visualization Center, DCD, but does have an instructor at the Terrain School at Ft Belvoir , VA, to teach weather effects on cross-country mobility and engineer missions.

The U.S. Army Aviation Warfighting Center (USAAWC) at Fort Rucker, AL, incorporates weather instruction and procedures into rotary-wing training programs in their mission areas. The center is the proponent for all Army Aviation including Unmanned Aerial Vehicle Systems (UAVS). The Center has requirements for weather observations and USAF forecast support at Cairns Army Airfield, Troy Municipal Airport (MAP), Alabama, and Andalusia MAP, Alabama. Additionally, Fort Rucker operates observing and communications equipment to relay weather intelligence and resource protection advisories to numerous Army remote training sites. Two active duty positions, aligned under the Directorate of Training and Doctrine (DOTD), are allocated to provide staff support for Army aviation and aviator training weather issues in areas of curriculum, concept development and doctrine. Staff weather personnel review training material and doctrine publications, provide advice to USAAWC staff and monitor developing

Figure 3-DOD-21. Meteorological Measuring Set- Profiler (MMS-P) obtains upper level wind data for artillery fires. (Photo courtesy U.S. Army.)

The USAAWC SWO also supports the U.S. Army Combat Readiness Center, Air Traffic Services Command, and other Fort Rucker tenants. Operational weather support for aircrews and resource protection are provided by Air Force contractors who are functionally aligned under the Directorate of Plans Training Mobilization and Security (DPTMS).

Beginning in FY 2004, ACC contracted day-to-day operational weather support to aviation operations at Fort Rucker (Cairns Army Airfield, Troy Municipal Airport, and Andalusia Municipal Airport) to 3D Research Corporation. ACC, through the same contract with 3D Research Corporation, also provides garrison airfield weather services (observing and/or forecasting) at Fort Belvoir, Fort Benning, Fort Knox, Fort Leonard Wood, Fort Huachuca, and Fort Sill.

Army National Guard (ARNG) Artillery

In FY 2005, the ARNG downsized its Meteorological (MET) Sections assigned to artillery units at Division level, Field Artillery Brigades (DIVARTY), and in Separate Brigades to two 6-soldier teams in the DIVARTY's, except in the Light DIV where there is one team, equaling a total of fifteen 6-soldier teams. In the ARNG "Modular Forces", there is one 6-soldier team per Fires Battalion in the Brigade Combat Team (BCT), providing 34 teams with six soldiers each, for 204 soldiers. In the Fires BDE there are 3 MET teams required per BDE providing 21 teams with 6 soldiers each, for a total of 126 soldiers. However, all Fires BDE TABs have authorizations for only one MET team for a total authorization for 42 soldiers. All together the ARNG has 246 soldiers authorized to Artillery Metrological Teams.

The ARTYMET sections provide upper air observations at least 39 training days each year supporting artillery live fire during Annual Training and monthly Inactive Duty Training. The ARTYMET sections support an average of 20 live fire training days and annually expend in excess of 100 balloons per section. The ARNG's ARTY MET Teams use the Meteorological Measuring Set (MMS), AN/TMQ-41A.

Army Corps of Engineers

The Corps of Engineers (COE) uses a network of about 10,850 land-based gages. About 55 percent of the sites collect meteorological data, 35 percent a combination of hydrologic and meteorological data, and 10 percent hydrologic or water quality data. The Corps funds or partially funds 58 percent (6350) of all the gages it uses. Meteorological gages commonly measure precipitation and temperature, as a minimum. Most sites also measure hydrological data. All data are used in the regulation of COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/National Weather Service (NWS) to collect and maintain precipitation information from 826 of meteorological sites. Similarly, COE transfers funds to the U.S. Geological Survey to maintain precipitation data collection from about 2000 sites, while the COE maintains the rest. Seventy-five percent of all Corps sites provide real-time data via satellite, microwaves, meterbursts, landlines, or radio. Data from COE gauging sites are available to other Federal, state and local agencies. All Corps data is made available to the National Weather Service. Most of the data is also used by other agencies.

United States Army Space and Missile Defense Command (USASMDC)

The High Energy Laser Systems Test Facility (HELSTF), an USASMDC directorate located on White Sands Missile Range, is an Army element of the DOD Major Range and Test Facility Base with the mission of high-energy laser (HEL) test and evaluation for future Army and sister Service HEL weapons. In addition to HEL systems test and evaluation, extensive use has been made of on-site laser systems to perform damage and vulnerability testing on laser-hardened materials, missile and aircraft components, and assorted battlefield equipment. The atmospheric sciences/meteorological mission is to support HEL testing by providing measurements of atmospheric conditions that are extremely important to propagation of any HEL beam thru the atmosphere (Figure 3-DOD-22). Many unique meteorological instruments are maintained to support this critical data collection for HBL testing. The HELSTF meteorological team also supports critical safety analysis of atmospheric dispersion for the very toxic laser fuels used. Efforts for FY 2007 include work required to modernize the atmospheric measurements and data collection/analysis capabilities needed to support new laser testing activities.

United States Army Kwajalein Atoll (USAKA) is a subcommand of USASMDC, which provides operational support for the Ronald Reagan Ballistic Missile Defense Test Site (RTS). The RTS (Figure 3-DOD-23) meteorological services support contractor provides meteorological support for range activities including missile operations within the atoll, intra-atoll transportation (marine and aircraft), remote island missile launches including Wake Island, and emergency operations support.

A full suite of surface and upper air observing equipment is available to support of these operations. Three, fixed upper air sounding systems are located on Kwajalein and Roi-Namur. Two portable upper air systems can be deployed to remote locations to provide upper air soundings. Additionally, one dual-polarized -Doppler S-band weather radar and one Doppler C-band weather radar, two DMSP/NOAA satellite receivers (one mobile) both having McIDAS display and management systems, one geostationary satellite receiver, and an intra-atoll mesonet and lightning detection network round out the sensors available to RTS forecasters. RTS, in cooperation with NASA/GSFC, continues to support global climate studies through the Tropical Rainfall Measurements Mission and the follow-on program of Global Precipitation Measurement and a smaller program of monitoring the solar-earth radiation flux for NOAA/BRL.

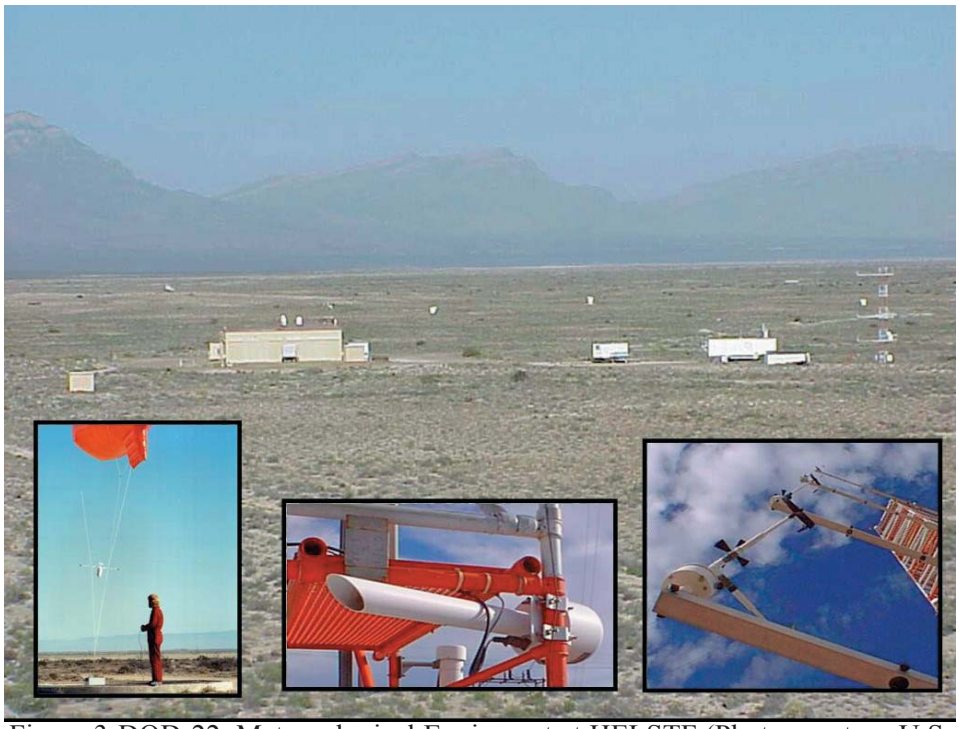


Figure 3-DOD-22. Meteorological Equipment at HELSTF (Photo courtesy U.S. Army.).

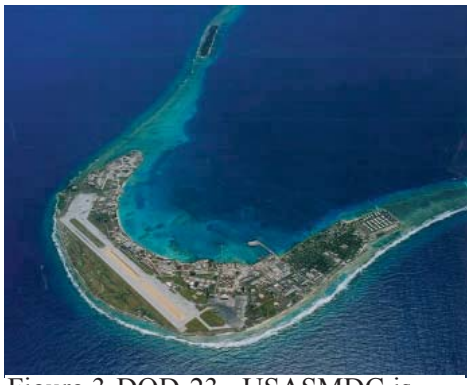


Figure 3-DOD-23. USASMDC is responsible for meteorological support to the Ronald Reagan Ballistic Missile Defense Test Site in the remote Kwajalein Atoll. Photo courtesy U.S. Army.

WEATHER SUPPORT FOR RESEARCH, DEVELOPMENT, TEST, AND EVALUATION (RDTE)

Under Army-AF agreement, the Army has responsibility for weather support for research, development, test, and evaluation (RDTE) to support Army ground combat missions as specified in AR 115-10/AFJI 15-157. The Corps of Engineers (COE), and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research related to soldiers performance in the range of weather conditions expected to be encountered in all theaters of operations. The Army Test and Evaluation Command (ATEC) is responsible for operational meteorological support to Army RDT&E.

Corps of Engineers (COE). The COE is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The Topographic Engineering Center (TEC), and the Cold Regions Research and Engineering Laboratory (CRREL), of COE's Engineer Research and Development Center (ERDC), develop Tactical Decision Aids (TDAs) to interpret the impact of weather on terrain to enhance Army operations. TDAs are transitioned to the Digital Topographic Support System (DTSS).

Under its military mission, the Engineer Research and Development Center's Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH, provides support to Army weapon systems RDTE with all-season solutions for mitigating adverse environmental effects on Army operations. CRREL conducts basic and applied research to investigate energy and mass transfer process at and near the terrain surface. Energy propagation and interaction across the electromagnetic, acoustic, and seismic spectral regions sees special emphasis, particularly with regard to dynamics in propagation caused by properties and processes of materials near the terrestrial surface. CRREL develops databases and models for predicting the state of the terrain including surface temperature, and tactical decision aids supporting mobility analysis and sensor performance. These products transition to various research and engineering programs including advanced technology demonstrations and specific programs of record such as the Commercial Joint Mapping Tool Kit. Recent efforts have included supporting materiel developers to simulate acoustic/seismic systems for the purpose of risk mitigation and trade-off studies.

Army Material Command (AMC). AMC is responsible for the research, design, development, test, and evaluation of equipment to satisfy the Army's requirements for meteorological support. AMC provides climatological and meteorological support to RDTE projects involving electro-optical sensors, atmospheric and obscurant effects on systems and their performance. It is also responsible for determining weather impact critical threshold values and the environmental sensitivities of battlefield systems, including soldiers. AMC has several Major Subordinate Commands (MSCs) and elements carrying out weather research and development responsibilities including the Research Development and Engineering Command (RDECOM), which has responsibility for the Army's Research Development and Engineering Centers (RDECs) and the Army Research Laboratory (ARL).

The Army Research Laboratory Battlefield Environment (BE) Division has a robust program in developing very high spatial and time resolution characterizations of the lower atmosphere using both measurements and numerical models. This research is particularly focused on characterizing and predicting higher resolution effects caused by complex and urban terrain. The focus of RDT&E is in the near-surface boundary layer domain that is most critical to Army applications. RDT&E includes characterizing aerosols and CBRN contaminants in the atmosphere and on predicting more general impacts of weather on Army systems, sensors, personnel and operations. Research addresses how to assimilate battlefield meteorological observations into diagnostic and prognostic numerical weather models and how to fuse forward area observations into these short term forecasts or "nowcasts" to correct for actual local conditions and improve actionable weather information.

The BE Division within the ARL Computational and Information Sciences Directorate (CISD), consists of three Branches shared between Adelphi, Maryland and White Sands Missile Range, New Mexico. The three branches combine basic and applied research programs in the areas of: meteorological modeling and modeling applications at high space and time resolution and the effects of complex terrain; atmospheric sensing of aerosols and contaminants using laser scattering, spectral analysis, multi-wavelength imagers, and lidars; atmospheric and aerosol propagation including electromagnetic and acoustic sig-

nal and target effects modeling; meteorological measurements as part of the "develop-verify-improve-verify" modeling and measurement cycle; and advanced weather impact decision aids for Command and Control and for Intelligence, surveillance, reconnaissance and target acquisition. The Division also provides liaison personnel between Army weather R&D and the coupled programs at the Air Force Weather Agency and the National Polar Orbiting Operational Environmental Satellite System (NPOESS) IPO. These positions focuses on coordinating technology transitioned from the BE Division into Army and AF fielded systems.

The BE Division and the Army Project Director- Integrated Meteorological System (PD-IMETS) office are partnering with AFW in new programs, such as the development of a common Joint Environmental Toolkit (JET). The Army IMETS Battle Command (BC) 6.4 software and several AFW system software baselines are to converge as a single weather forecasting software tool. The Army will add command and control interfaces and weather effects tactical decision aid products such as the Tri-Service Weather Effects Decision Aid (TS-I WEDA). The combined JET-IMETS software will transition to the Distributed Common Ground Station-Army (DCGS-A) and Army software Block 2 to enhance weather capabilities for net-centric Army support. POR IMETS weather products can be accessed through a web-browser, client server applications, or overlaid on the user's Common Operational Picture (COP) through web services such as publish and subscribe (PASS). Current client applications will be web-enabled over time. IMETS technologies will continue to provide net-centric weather support to Army Battle Command and Future Combat Systems (FCS) as DCGSA Weather Services.

The Meteorological Modeling Branch conducts a research program in the micrometeorological and mesoscale-gamma (small end of mesoscale) processes and structure of the atmospheric boundary layer at scales generally smaller than a few kilometers. This program focuses on the complex interactions of the land-air interface with wind fields, turbulence, and fluxes in terrains that range from open rolling grasslands to mountains and from forest canopies to urban canyons. Detailed modeling of aerosol and chemical-biological transport and dispersion in this wide variety of tactical environments are addressed. A range of numerical weather models are addressed, including non-hydrostatic predictive and diagnostic gridded meteorological models. Diagnostic models are fed with near real-time observations from lidar, sonic anemometers and other battlefield sensors to produce rapid refresh analyses for urban domains and complex terrain. Short term 2-3 hour local "nowcasting" and "Weather Running Estimate" products are being developed to improve the confidence in actionable weather intelligence for future Army systems. The integration of next generation ensemble forecasts and development of measures of confidence to improve decision making are being performed.

The Atmospheric Effects Branch performs research on the basic characteristics of the atmosphere as they will affect new sensing technologies and systems. The branch designs and executes experiments to verify and improve the new diagnostic and prognostic numerical weather models and atmospheric effects on sensors and systems. Technology is developed to more easily capture forward area environmental data and information in near real-time in a networked environment. The branch also is responsible for producing and verifying tactical decision aids and models to assess atmospheric effects and impacts on weapon systems, sensors, and personnel. Weather knowledge management tools are developed for Army C2 and ISR systems including automation of Intelligence Preparation Battlefield (IPB) and weather optimization of route planning into mission planning and execution for unmanned ground and aerial vehicles. Controlled field measurements are performed to develop or verify theoretical models for atmospheric and optical turbulence, acoustic propagation, radar propagation, wind flow in small scale urban domains and desert aerosol production.

The Atmospheric Sensing Branch is working to enhance warfighter situational awareness through the utilization of advanced atmospheric instrumentation and novel characterization techniques. They are developing, testing, evaluating, and implementing novel polarimetric imaging techniques to analyze effects from surface contaminants for target recognition and identification. Research on real-time four-dimensional monitoring of the atmosphere using remote sensing techniques will provide war fighters and homeland defense with a realistic understanding of the atmosphere for its effects on CBRNE. This research also includes modeling the effects of forest canopies on acoustic propagation and investigating the use of beam-forming techniques for the mitigation of the effects of the atmosphere on sensors, systems, and soldiers.

The Army Research Office, Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with understanding the dynamical and physical processes of the atmospheric boundary layer at scales of interest to the Army (millimeters to 10's of kilometers) through measurements, simulations, and theoretical considerations. The basic research program is conducted through the peer-reviewed, individual investi-

gator program and occasional special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby leading to better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on airflow, and the development of natural obscurations throughout the diurnal cycle. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales. Special funding areas are also managed. The Defense University Research and Instrumentation Program (DURIP) provides funds for instrumentation needed to support ongoing research activities. The Defense Experimental Program to Stimulate Competitive Research (DEPSCoR) participation is a competition restricted to universities in certain states that compete for additional basic research funds. Also basic research under the Small Business Innovative Research Program (SBIR) is managed for selected topics. The primary research focus continues on the analysis and understanding of the stable boundary layer, which is augmented by external funding as a special program. New initiatives include development of a plan for a Soldier Scale Atmospheric Test Bed to examine the diurnal boundary layer process and studies of stable boundary layers in complex terrains.

Communications Electronics Command (CECOM), a major subordinate command of AMC, provides support to developing and fielding weather programs through the following organizations Logistics Readiness Center (LRC), Research, Development and Engineering Center (RDEC), Software Engineering Center (SEC), and Safety office. The CECOM LRC is the level II manager of the Meteorological Measuring Set (MMS) program.

RDEC's Communications-Electronics Research Development Engineering Center (CERDEC), Intelligence and Information Warfare Directorate provides technical management and support to the Program Manager, Intelligence and Effects and Program Manager, Night Vision/Reconnaissance, Surveillance, and Target Acquisition for the IMETS and the MMS Profiler. A brief description of each of these programs shows CECOM's involvement.

Meteorological Measuring Set (MMS), AN/TMQ-41. The MMS is an upper air meteorological data collection, processing and dissemination system that provides data to the field artillery and target acquisition users. The system is a non-developmental item (NDI). All active Army units and National Guard Bureau are equipped with the MMS.

The Meteorological Measuring Set-Profiler (MMS-P) AN/TMQ-52 System. The Meteorological Measurement Set-Profiler (MMS-P) is a major improvement over the MMS. The AN/TMQ-52 design will support the new generation of artillery weapons. The system will include frequent and update meteorological messages that enhances the meteorological validity over a larger battle space than the current equipment. The MMS-P uses the MMS mesoscale meteorological model to assimilate data from a variety of sources to provide the best meteorological messages to the user in a timely fashion. The system receives data from ground-based sources, radiosondes, and satellite-based sources, (such as boundary data from communications satellites and, in a future program block improvement, polar orbiting meteorological satellites) through onboard satellite receiving capability. The data affects the operation of the mesoscale meteorological model and for post-processing of the data in order to generate meteorological messages. Finally, an operator interface, in conjunction with the message generation and formatting software, facilitates communication between the MMS-P and all other systems that require interoperability with the MMS-P. Four System Design and Development (SDD) models have been produced. Developmental testing has been successfully completed and Low Rate Initial Production (LRIP) was approved at a MS C decision in FY 2003. The Profiler system has completed Initial Operational Test and Evaluation (IOTE) FY 2005. Full Rate Production (FRP) was approved at a FRP Decision in FY 2005.

The Intelligence and Information Warfare Directorate (I2WD), Communications Electronics Research & Development Engineering Center (CERDEC), Research Development & Engineering (RD&E) Command is providing technical and sustainment support to the Program Director-IMETS.

The IMETS comes in two basic configurations known as the Vehicle Mounted (AN/TMQ40B/C/D) and Light (AN/GMQ-36/36A/36B) groups. The IMETS Vehicle Mounted group has three variants, all with the same function that differ only by vehicle, shelter, and/or generator (Figure 3-DOD-24). The new IMETS-Light (AN/GMQ-36A) provides a transit case version of the IMETS with the same software capabilities as the vehicle version.

Either the IMETS Vehicle Mounted or the IMETS Light configuration can provide the weather component of the Intelligence Electronic Warfare (IEW) sub-element of the Army Battle Command System (ABCS). IMETS has been designated by the DCGS as the Weather Center for DCGS-A weather

Figure 3-DOD-24. IMETS Vehicle Mounted Configuration. (Photo courtesy U.S. Army.)

requirements and is on track to fully support the Future Combat System (FCS) prime. The IMETS at Div and Corps levels provides commanders at all echelons with an automated tactical weather system that receives, processes and disseminates weather observations, forecasts, battlefield visualization, and weather effects decision aids to all Army Tactical Command and Control System (ATCCS) Battlefield Functional Areas (BFAs). IMETS can receive weather information from (either USA, European, Japanese, or Chinese civilian) geostationary satellites depending on the system's location, civilian forecast centers, the Air Force Weather Agency, artillery meteorological sections and remote sensors. IMETS processes and collates forecasts, observations, and climatological data to produce timely and accurate weather products tailored to the specific war-fighters needs. Significant weather and environmental support to war-fighters are the weather applications such as the automated tactical decision aids and contours client. These weather products display the impact of the weather on current or planned operations for both friendly and enemy forces. Weather products can also be overlaid on the Common Operational Picture (COP) or Common Tactical Picture (CTP) accessed by using a browser, and is executed on the users terminal through weather client implementations.

Major test events in FY 2005 include the IMETS Intra-Army Interoperability Certification test, completed during the first quarter of FY 2005, at the Central Test Support Facility (CTSF) and the ABCS 6.4 Good Enough (GE) Operational Evaluation (OPEVAL) completed in second quarter FY 2005. The AN/TMQ-40C Materiel Release is on schedule to occur at the last quarter of FY 2005, and the AN/TMQ-40D for FY 2006. Both of these systems, along with the AN/GMQ-36 are on schedule to field to units. In order to streamline the acquisition process, the IMETS AN/GMQ36A/B has been given permission to go directly to Materiel Release pending the results of Development Testing and skip Milestone C pending on Development Testing results. FY 2005 efforts will focus on the ABCS 6.4 GE Operational Assessment and fielding and the IMETS Light (AN/GMQ-36A/B) Materiel Release and fielding decision, along with finishing the fielding efforts for the AN/GMQ-361 to gaining units including the Stryker Brigade. AN/TMQ40B/C/D systems will also be fielded during FY 2005.

Army Test and Evaluation Command (ATEC)

The Developmental Test Command (DTC), a subordinate command of U.S. Army Test and Evaluation Command (ATEC), is responsible for providing operational meteorological support to eight Army ranges and test sites. Under responsibilities established in AR 115-10/ AFJI 15-157, the DTC meteorological units provide meteorological data collection and analysis, consultation, and weather forecast and warning services to support Army and other DOD research, development, test and evaluation (RDT&E) activities at eight Army installations. Funding for the Army RDT&E Meteorology Program under Program Element 665702 is sufficient to maintain the basic meteorological support infrastructure at Army RDT&E ranges and sites. However, instrumentation needed to support unique or test-specific requirements generally must be funded by test sponsors. Because the majority of the operational meteorological support workforce at the Army ranges is or soon will be eligible to retire, the Program has implemented an intern program to recruit and train entry-level scientists and technicians to ensure continuity in specialized meteorological support services as senior employees begin to retire.

The Army RDT&E Meteorology Program has entered into a multi-year working relationship with the National Center for Atmospheric Research (NCAR) to enhance "range scale" (mesoscale to microscale) forecast and analysis capabilities at the Army test ranges. The principal product of this relationship is the Four-Dimensional Weather (4DWX) System, which consists of a central data archival/retrieval system for all range and external meteorological and model data, a high-resolution mesoscale meteorological model (MM5), and a variety of user-configurable displays. The MM5 mesoscale model is used operationally in both predictive and analytic modes to provide detailed information about the past, current, and future structure of the atmosphere over the Army's test ranges. ATEC 4DWX capabilities include MM5-based real-time four-dimensional data assimilation (RT-FDDA) at the major Army test ranges and 4DWX On the Move (OTM), a globally-relocatable mesoscale modeling system to support Army RDT&E (including DTC distributed and virtual testing) at locations other than the Army ranges. In FY 2007, the 4DWX program will continue the transition of

its operational mesoscale model from MM5 to the next-generation Weather Research and Forecast (WRF) model. The NCAR/ATEC version of WRF includes the full observation nudging capabilities of the MM5-based RT-FDDA system. Output from mesoscale model forecasts and analyses is used as meteorological input to atmospheric dispersion, noise propagation, ballistic trajectory, and other range applications models to simulate many tests and their associated impacts. The 4DWX system contributes to improved test planning and conduct, selection of more representative locations for test sensors, inclusion of realistic atmospheric effects in virtual testing, and forensic analyses of meteorological effects on test results.

The Chief of the Meteorology Division at Dugway Proving Ground's West Desert Test Center serves as the Program Manager for Meteorological Support to Army RDT&E. Under Program Element 0605384, the Division's Modeling and Assessment Branch also provides the following specialized services:

1. technical assistance to the DTC operational meteorological teams/branches;
2. atmospheric model verification and validation, including algorithm evaluation and the generation of validation data sets; and
3. technical assistance to the DOD CB defense modeling community in the development of new CB hazard assessment models.

Division employees also serve on various national and international committees addressing issues related to meteorological measurements, atmospheric dispersion modeling, and CB hazard assessment.

Army Medical Research and Material Command

The U.S. Army Research Institute of Environmental Medicine (USARIEM) conducts basic and applied research on the effects of heat, cold, high terrestrial altitude and nutritional status on the health and performance of individual soldiers and combat crews operating Army systems.

Applied research in thermal physiology and biophysical modeling is directed towards improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to local weather parameters (primarily ambient temperature, dew point, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The overall goals of USARIEM weather-related research programs are to develop methods to effectively monitor and, where possible, extend the operational envelope for both training and operational scenarios.

Weather-related research efforts include the development and validation of automated methods to integrate thermal strain prediction models with real-time weather information resources relevant to dismounted infantry operations. Temporal and spatial scales of interest are meters to kilometers and minutes to several days. USARIEM is working through an MOA with the Army Research Laboratory Battlefield Environment Division to implement thermal models on Personal Digital Assistant (PDA) devices and the Integrated Weather Effects Decision Aid (IWEDA).

The availability of ground level environmental data at high temporal and spatial resolution continues to pose a significant challenge for predictive model development and validation. As part of the warfighter physiological status-monitoring (WPSM) program, USARIEM is investigating methodologies needed to integrate real-time local environmental data and warfighter physiological data with predictive model processes. The effective fusion of these two real-time data streams will enable near term environmental strain and performance status predictions for individual warfighters.

A miniature weather station developed under a Small Business Innovative Research (SBIR) project has been refined into a 1 kg battery powered unit which may be used to collect meteorological data to support the prediction of thermal stress on the WPSM system. Research efforts in this area are intended to address capabilities identified in the Operational Requirements Document (ORD) for the Army's Land Warrior program.

DEPARTMENT OF TRANSPORTATION WEATHER PROGRAMS

The Federal Aviation Administration (FAA) has the responsibility to provide national and international leadership in the optimization of aviation weather systems and services. This leadership is manifested through the management of a safe and efficient National Airspace System (NAS) and the encouragement of consensus and cooperation between government agencies, private weather services, research organizations, and user groups involved in aviation weather. The Federal Highway Administration (FHWA) manages programs that provide federal financial and technical assistance to the states, promotes safe commercial motor vehicle operations, and provides access to and within national forests and parks, native American reservations, and other public lands. Safety, efficiency, and mobility in these programs requires the incorporation and use of timely weather and road condition information. The Federal Railroad Administration promotes and regulates railroad safety. It also sponsors research to enhance railroad safety and efficiency, including support for improved collection, dissemination, and application of weather information to reduce hazards to train operations and to railroad employees. The Federal Transit Administration's mission is to ensure personal mobility and America's economic and community vitality by supporting high quality public transportation through leadership, technical assistance and financial resources.

FEDERAL AVIATION ADMINISTRATION

THE NATIONAL AIRSPACE SYSTEM OF THE FUTURE

In a proactive stroke to broaden the capabilities of the National Airspace System for the future, the 108th Congress and President Bush took the first critical step toward transforming our air transportation system by passing and signing into law *VISION 100 - Century of Aviation Reauthorization Act (P.L. 108-176)*. *VISION 100* calls for an integrated, multi-agency plan to transform the nation's air transportation system to meet the needs of the year 2025 while providing substantial near-term benefits. This Next Generation Air Transportation System (NGATS) Initiative will address critical safety and economic needs in civil aviation while fully integrating national defense and homeland security improvements into this future system.

Along with the private sector and academic community, the Federal Aviation Administration, NASA, the Departments of Commerce, Defense, Homeland Security, Transportation, and the White House Office of Science and Technology Policy are working together to design and build the NGATS.

The first product of this landmark effort was an *Integrated National Plan* delivered to Congress in December 2004. This strategic business plan lays out a common vision for the NGATS, establishes benchmarks for our success, and establishes a structure by which we can design and implement the changes we need to make. *VISION 100* also created the Joint Planning and Development Office (JPDO). Jointly managed by the FAA and NASA, and supported by staff from all the agencies involved, the JPDO serves as a focal point for coordinating the research related to air transportation for all of the participating agencies.

Overseeing the work of the JPDO is a Senior Policy Committee chaired by the Secretary of Transportation that includes senior representatives from the participating departments and agencies and the Director of the Office of Science and Technology Policy. Among its key responsibilities, the Senior Policy Committee provides policy guidance and review; makes legislative recommendations; and identifies and aligns resources that will be necessary to develop and implement the *Integrated National Plan*. DOT Secretary, Norman Mineta, chaired the first meeting of the Senior Policy Committee on September 26, 2003.

The JPDO has defined eight strategies that are the first steps towards creating the roadmap for NGATS. While the strategies deal with transforming specific areas of the air transportation system, they make up a larger whole and will integrate the sum of the efforts into building the NGATS system. The transformation strategies are:

- Develop Airport Infrastructure to Meet Future Demand.
- Establish an Effective Security System without Limiting Mobility or Civil Liberties.
- Establish an Agile Air Traffic System.
- Establish User-specific Situational Awareness.
- Establish a Comprehensive Proactive Safety Management Approach.
- Ensure Environmental Protection that Allows Sustained Economic Growth.
- Develop a System-wide Capability to Reduce Weather Impacts.
- Harmonize Equipage and Operations Globally.

For each of the eight *Integrated National Plan* strategies an an integrated product team (IPT) was formed.

The IPTs will be made up of government and private sector experts with extensive aviation experience. The IPTs will be responsible for applying best private and public sector practices to achieve that particular strategy's mission and objectives. The primary responsibility for assembling and leading each IPT belongs to one Federal agency.

The IPTs will establish detailed action plans that will break the project down into manageable tasks. Specific IPT activities include:

- Managing the planning and orchestrating the execution of all relevant work to complete the assigned strategy;
- Conducting analyses and trade studies to select and validate implementation alternatives;
- Analyzing changes currently underway, identifying gaps, and establishing the required Government and/or industry research and development activities to close necessary gaps;
- Coordinating with Government and private industry on research and development resources;
- Collaborating with industry on research and implementation for the initiative;
- Identifying non-technical approaches such as policy, regulation, and operational procedures;
- Establishing detailed requirements for individual mission areas;
- Conducting advanced concept and technology demonstrations;
- Creating a transition plan for implementation of products; and
- Creating public/private partnerships that include multi-agency, industry, and Government participation.

The JPDO is responsible for approving broad strategies of the IPTs as part of the *Integrated National Plan* and ensuring IPT plans and schedules are consistent with the roadmap and architecture.

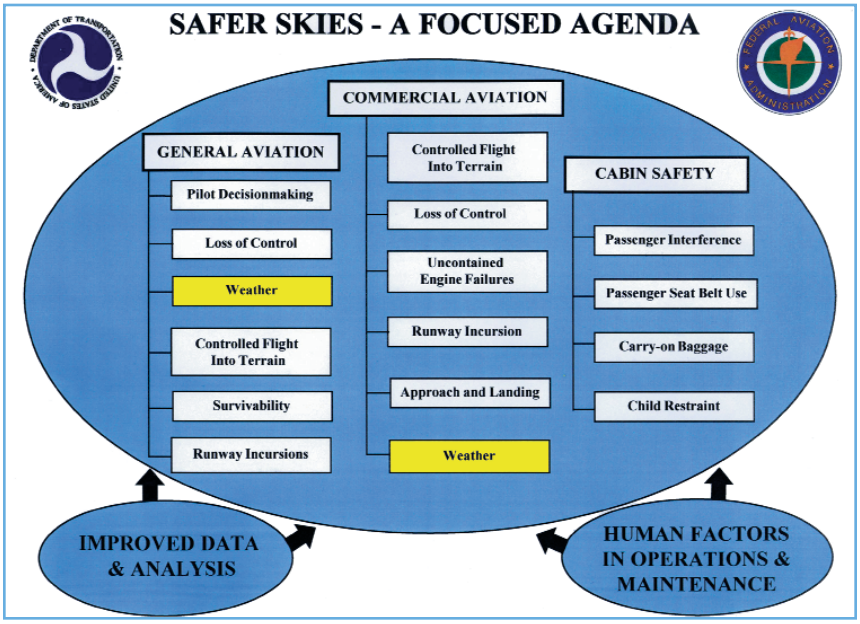
In addition, the NGATS Institute will support the NGATS mission by recruiting, selecting, and assigning private sector experts and technical resources to participate on IPTs and perform technical work for the IPTs and JPDO. These efforts will guarantee the establishment of a collective enterprise among key stakeholders to achieve the transformation, as well as to ensure that a process is created that is transparent and fully open to public scrutiny.

AVIATION WEATHER MANAGEMENT

Although the Department of Commerce's National Weather Service has the lead for the Weather IPT within the JPDO, the Federal Aviation Administration (FAA) continues to have the leadership role for the national aviation weather program requirements. As the leader, FAA must conduct continual coordination for identifying needs for aviation weather products and services among the Air Traffic Control organization, the aviation industry components and among service providers. The coordination process leads to opportunities to leverage efforts and resources to form partnerships in finding solutions in response to the needs. The *National Aviation Weather Program Strategic Plan* and the *National Aviation Weather Initiatives* are two documents that formalize the coordination and partnerships.

The FAA focus for aviation weather has been to promote safety first; then improve the NAS efficiency to reduce delays and re-routing due to weather. The Administrator has launched *The Safer Skies, A Focused Safety Agenda* which includes a government/industry Commercial Aviation Safety Team (CAST) and Joint Safety Analysis Teams (JSAT) to evaluate accident investigation reports to analyze the series of events leading to the accidents, and get a sense of what and how decisions were made in the course of the flight. Other teams, Joint Safety Implementation Teams (JSIT), using the findings of the JSAT, develop and recommend intervention actions to eliminate or reduce the causes or improve the actions in the decision making process. Training about the decision making process has been identified by these teams as a major part of the solution.

Aviation weather information is complex and highly perishable, is most useful when customers can successfully plan, act, and respond in ways that avoid accidents and delays. FAA will improve the ability of the aviation community to use weather information through a review and upgrade of airmen training and certification programs. FAA will also develop multi-



media training tools to support aviation safety and training initiatives. Funding has been requested to further this effort.

Weather has been made a standard consideration in all aspects of the operation and architecture of the NAS. Aviation weather needs from the field, Federal agencies, and industry are entered into the FAA Acquisition Management System (AMS) through which all new programs and changes to the NAS are processed, evaluated, validated, engineered to a requirement, and acquired. The new Air Traffic Organization (ATO) Service components have the responsibility to guide all initiatives through the AMS process and organization, including the Integrated Requirements Team, the Integrated Product Team, and the Decision Boards; to assure the development continues to meet the original need; and to guide the activity should the need evolve. Improvements to the AMS process facilitate non-system or non-hardware (e.g., service improvement or rule changes) solutions receiving the same rigorous evaluation and validation.

FAA has established an Aviation Weather Technology Transfer (AWTT) Board which addresses the key issues involved in bringing new weather capabilities in to the operational system. At key decision points, the board evaluates the maturity of the capability, its integration into the existing system, its supportability in the field, and the training program to prepare the users.

FAA relies on other Federal agencies for weather services and support, especially NOAA's National Weather Service (NWS) and its Aviation Weather Center. Requirements validated by FAA for domestic and International Civil Aviation Organization (ICAO) users are coordinated annually and supported through the agencies and contractual arrangements. All agencies' efforts in the area of aviation weather services are coordinated for use by everyone, as appropriate. Aviation weather technology includes the ways in which aviation weather information is gathered, assimilated, analyzed, forecast, disseminated, and displayed. The development of this technology also demands that consideration be given to human factors and the application of decision-making tools. FAA will support the use of technology to improve aviation weather information through integration of Federal and non-Federal resources. Automation, improved product and graphics generation, and dissemination to the cockpit are being developed as early opportunities to achieve these goals.

AVIATION WEATHER ACQUISITION AND SERVICES

One of the primary functions of the FAA ATO organization is the development and management of requirements for the FAA *Capital Investment Plan*. Recent projects in the Acquisition Management System (AMS) have focused on weather detection and display systems for pilots and air traffic controllers to ensure that aircraft avoid hazardous weather. The following paragraphs describe many of those projects.

The Integrated Terminal Weather System (ITWS) will integrate weather data from sensors in the terminal area to provide and display compatible, consistent, real-time products that require no additional interpretation by controllers or pilots--the primary users (Figure 3-DOT-1). ITWS will use data from automated surface observing systems, Doppler weather radars, and low-level wind-shear alert systems, together with NWS data and products, to forecast aviation impact parameters, such as convection, visibility, icing, and wind shear, including down bursts.

ITWS has been installed at 10 locations, of which 9 are in service. Installations are planned at 11 additional

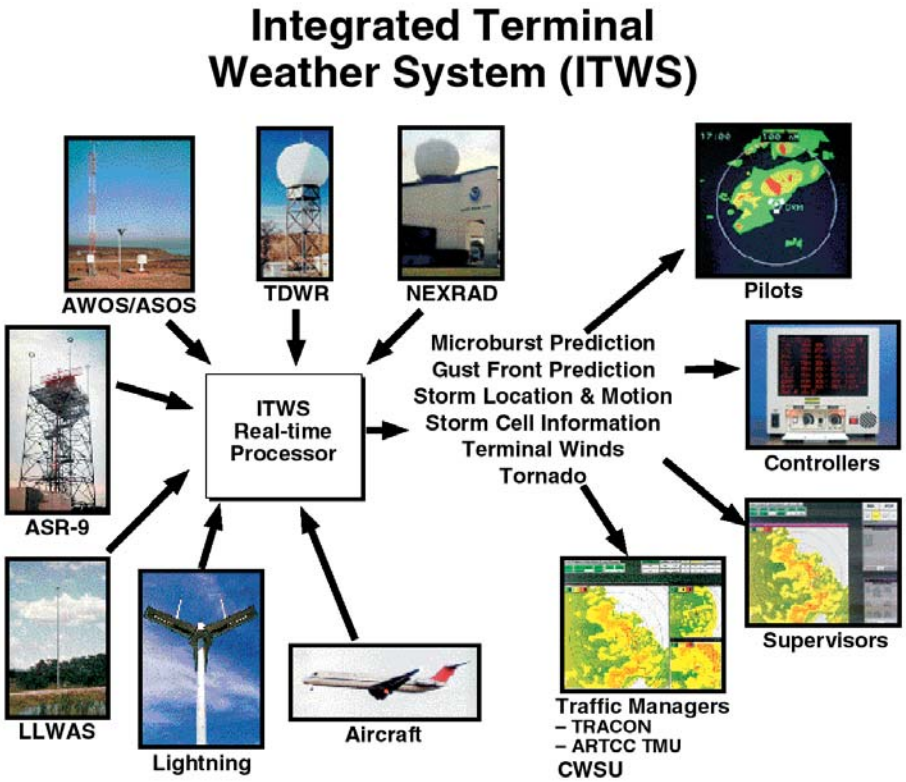
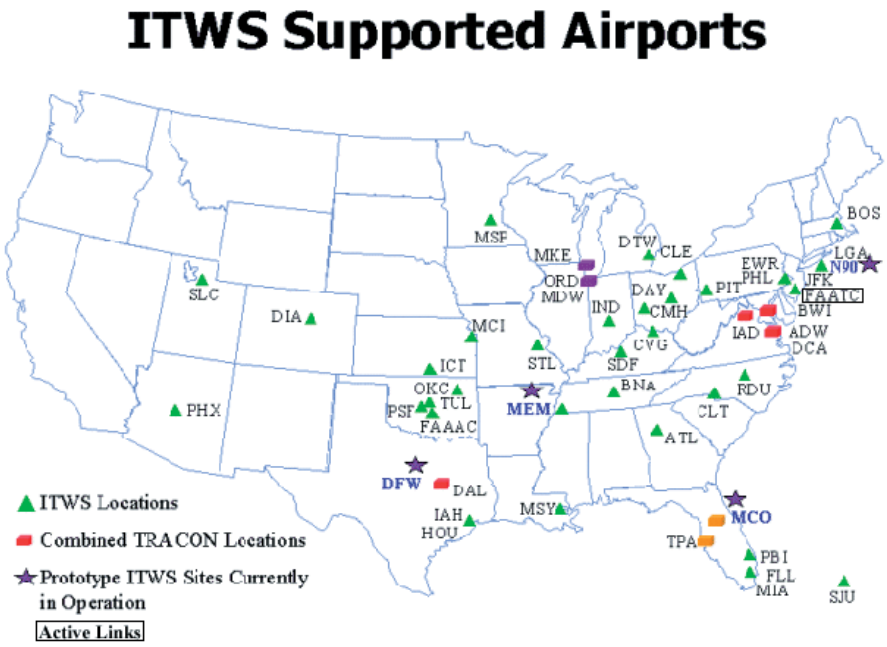


Figure 3-DOT-1. The ITWS integrates data from FAA and NWS sensors and systems to provide a suite of weather informational products.



locations by FY 2009. The current long range program has been limited to 22 ITWSs, which will cover about 30 high-activity airports that are supported by terminal doppler weather radars.

The Corridor Integrated Weather System (CIWS) is a demonstration program which will take some of the capabilities of the integration software of the ITWS and expand it to cover larger areas beyond the terminals. 'Corridor' in the name implies the area covered will be an elongated zone which may include a number of terminal areas. The demonstration area extends from Boston southward over New York as far as Washington and westward over Pittsburgh and Cleveland connecting to Chicago. The CIWS is expected to integrate information from the WSR-88D and ASR-9 radars and other observing sensors in the corridor to produce weather information products focused on current conditions affecting en route traffic in the corridor (Figure 3-DOT-2). It will produce two hour forecasts with trend information and a high-resolution echo tops product. There will be twelve sites, including six in the ARTCCs and one at the Command Center. The comprehensive plan calls for implementation by 2009; however the funding stream has been interrupted in 2006 which may delay implementation to a later year

Figure 3-DOT-2. Corridor Integrated Weather System (CIWS) Display

The Terminal Doppler Weather Radar (TDWR) program consisted of the development, procurement, and installation of a new terminal weather radar based on Doppler techniques. TDWR units have been located to optimize the detection of microbursts and wind shear at selected airports with high operations and frequent weather impacts. In addition, TDWR has the capability to identify areas of precipitation and the locations of thunderstorms (Figure 3-DOT-3).

Microbursts are weather phenomenon that consists of an intense down draft with strong surface wind outflows. They are particularly dangerous to aircraft that are landing or departing. TDWR scanning strategy is optimized for microburst/wind shear detection. The radars are located near the airport operating areas in a way to best scan the runways as well as the approach and departure corridors. The displays are located in the tower cab and Terminal Radar Approach Control (TRACON).

The FAA has 47 TDWR systems. A software upgrade will integrates TDWR and low level wind shear alert system data has been integrated at 9 high traffic/high weather threat airports.

The Low Level Wind Shear Alert System (LLWAS) provides information on hazardous wind shear events that create unsafe conditions for aircraft landings and departures. A total of 110 airports have LLWAS. The 101 basic systems, LLWAS-2, consists of a wind sensor located at center field and 5 to 32 sensors near the periphery of the airport (Figure 3-DOT-4). A computer processes the sensor information and displays wind shear conditions on a ribbon display to air traffic controllers for relay to pilots. The improvement phase, referred to as LLWAS-Relocation/Sustainment (LLWAS-RS), will include expanding the network of sensors, developing improved algorithms for the expanded network, and installing new information/alert displays. The new information/alert displays will enable controllers to provide pilots with head wind gain or loss estimates for specific runways. These improvements will increase the system's wind shear detection capability and reduce false alarms. Improvements are also expected to reduce maintenance costs. LLWAS-

Figure 3-DOT-3. FAA Terminal Doppler Weather Radars provide supplementary wind and precipitation conditions for airport approach and departure.

RS deployment was completed this year.

The Weather Systems Processor (WSP) program provides an additional radar channel for processing weather returns and de-alias returns from the other weather channel in the ASR-9. The displays of convective weather, microburst, and other wind shear events will provide information for controllers and pilots to help aircraft avoid those hazards. All 34 units are in place and operating. Also, there is one mobile system in operation.

The Terminal Weather Information for Pilots (TWIP) program provides text message descriptions and character graphic depiction of potentially hazardous weather conditions in the terminal area of airports with installed TDWR systems. TWIP provides pilots with information on regions of moderate to heavy precipitation, gust fronts, and microburst conditions. The TWIP capability is incorporated in the TDWR software application. Text messages or character graphic depiction are received in the cockpit through the Aeronautical Radio Incorporated (ARINC) Communication Addressing and Reporting System (ACARS) data link system. A total of 47 TDWR systems are deployed, installed and commissioned. The TWIP capability is operational at most of the TDWR sites. Activation of TWIP at the remaining sites is dependent on availability of National Airspace Data Interchange Network (NADIN) II connectivity and program funding.

The Flight Information System (FIS) Policy was implemented during FY 2001, through Government-Industry Project Performance Agreements (G-IPPAs) with two industry FIS data link service providers (ARNAV Systems, Inc. and Honeywell International, Inc.). Through the government-industry agreements, the FAA provides access to four VHF channels (136.425-136.500) in the aeronautical spectrum while industry provides the ground infrastructure for data link broadcasts of text and graphic FIS products at no cost to the FAA. Under the agreements, a basic set of text products are provided at no cost to the pilot users while industry may charge subscription fees for other value-added text and graphic products.

The FAA FIS data link program will continue development of necessary standards and guidelines supporting inter-operability and operational use. In addition, the need and feasibility for establishing a national capability for collecting and distributing electronic pilot reports (E-PIREPs) from low-altitude general aviation operations is being evaluated. A concept analysis has been initiated to define the need for transition and evolution of FIS data link services supporting the future NAS architecture including Free Flight operations.

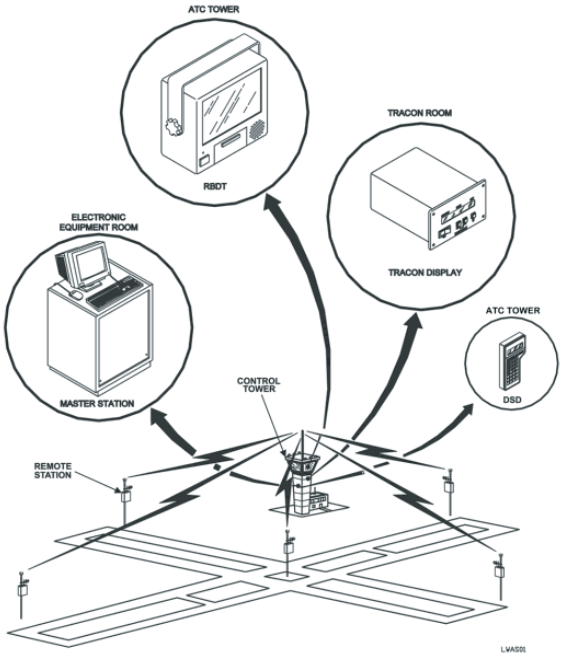


Figure 3-DOT-4. LLWAS equipment on an airfield.

SURFACE WEATHER OBSERVING PROGRAM

Aviation Weather Observations. The FAA has taken responsibility for aviation weather observations at many airports across the country. To provide the appropriate observational service, FAA is using automated systems, human observers, or a mix of the two. It has been necessary to place airports into four categories according to the number of operations per year, any

special designation for the airport, and the frequency at which the airport is impacted by weather.

Level D service is provided by a stand-alone Automated Weather Observing System (AWOS) or an Automated Surface Observing System (ASOS). In the future, Level D service may be available at as many as 441 airports.

Level C service includes the ASOS/AWOS plus augmentation by tower personnel. Tower personnel will add to the report observations of thunderstorms, tornadoes, hail, tower visibility, volcanic ash, and virga when the tower is in operation. Level C service includes about 301 airports.

Level B service includes all of the weather parameters in Level C service plus Runway Visual Range (RVR) and the following parameters when observed--freezing drizzle versus freezing rain, ice pellets, snow depth, snow increasing rapidly remarks, thunderstorm/lightning location remarks, and remarks for observed significant weather not at the station. Level B service includes about 58 airports.

Level A service includes all of the weather parameters in Level B service plus 10-minute averaged RVR for long-line transmission or additional visibility increments of 1/8, 1/16, and 0 miles. Level A service includes about 70 airports.

Automated surface aviation weather observing systems will provide aviation-critical weather data (e.g., wind velocity, temperature, dew point, altimeter setting, cloud height, visibility, and precipitation type, occurrence, and accumulation) through the use of automated sensors. These systems will process data and allow dissemination of output information to a variety of users, including pilots via computer-generated voice.

Automated Weather Observing Systems (AWOS) was deployed at over 200 airports to provide the basic aviation weather observation information directly to pilots approaching the airport. The majority of these systems were installed at various non-towered airports to enhance aviation safety and the efficiency of flight operations by providing real-time weather data at airports that previously did not have local weather reporting capability. These systems are built to the standards of quality necessary to ensure the safety of flight operations and are available off-the-shelf as a commercial product. There remain 198 AWOSs.

Automated Surface Observing Systems (ASOS). In a joint program with NOAA NWS, the FAA has procured, installed, and operates ASOS at the remaining airports where the FAA provides observations and at additional non-towered airports without weather reporting capabilities in accord with the levels of service listed above. Production is complete and the FAA has 569 systems installed and commissioned.

Aviation Weather Sensor Systems (AWSS), a new program, will have capability similar to ASOS (Figure 3-DOT-5). However, the AWSS is a direct acquisition of the FAA--not from the joint ASOS program. Production was completed in CY 2005.

The AWOS/ASOS Data Acquisition System (ADAS) functions primarily as a message concentrator and will collect weather messages from AWOS and ASOS equipment located at controlled and non-controlled airports within each ARTCC's area of responsibility. ADAS will distribute minute-by-minute AWOS/ASOS data to the Weather and Radar Processor (WARP) within the air route traffic control center in which it is installed. ADAS will also distribute AWOS data to the NADIN which will in-turn forward the data to the Weather Message Switching Center Replacement (WMSCR) for further distribution. Field implementation of ADAS is complete.

The Automated Lightning Detection and Reporting System (ALDARS) is a system adjunct to the ADAS. ALDARS collects lightning stroke information from the National Lightning Detection Network (NLDN) and disseminates this data to AWOS/ASOS for the reporting of thunderstorms in METAR or SPECI observations, when appropriate. The use of ALDARS eliminates the need for manual reporting of thunderstorms and increases the number of airports where thunderstorms will be reported. ALDARS is completely operational.

Stand Alone Weather Sensors (SAWS) are back-up systems for some AWOS/ASOS sensors at locations where no other back-up capability is available. SAWS have been demonstrated and full delivery is nearly completed. The full deployment will comprise up to 307 units.

Figure 3-DOT-5. Aviation Weather Sensor Systems an ASOS like supplement for observations.

ASOS Controller Equipment- Information Display System (ACE-IDS) is an electronic cabinet of displays available to the controller at his work station (Figure 3-DOT-6). It provides graphics of information which comes from many sources that originate at many nodes of an LAN which includes, but is not limited to, weather related parameters, observations, and other automated weather products. This system is designed specifically to support operations in high-volume, high-tempo Terminal Radar Approach Control (TRACON) facilities. They are installed at the following TRACONs: Atlanta, Boston, Dallas-Fort

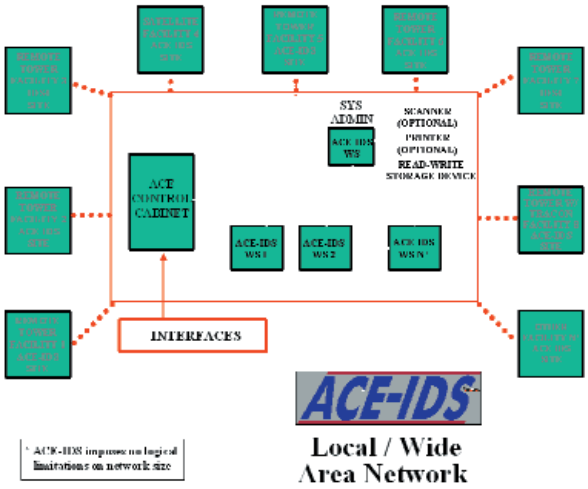


Figure 3-DOT-6. ASOS Controller Equipment- Information Display System (ACE-IDS)

Worth, Honolulu, Northern California (San Francisco), Oklahoma City, Potomac (Wash. D.C.), Saint Louis, and Seattle.

AWOS for Non-Federal Applications. Under the Airport Improvement Program (AIP), state and other local jurisdictions may justify to the FAA their need to enhance their airport facilities. Upon approval, these improvements may be partially funded by the FAA using resources from the Airway Trust Fund. The local airport authority becomes responsible for the remainder of the funding necessary to complete the procurement, as well as the funding for the regular maintenance. The addition of an AWOS is one of the improvements that qualify for AIP funding assistance. Systems that qualify must meet certain standards which are defined in an FAA Advisory Circular on *Non-Federal Automated Weather Observing Systems.*

There are more than 275 non-Federal AWOS locations. Some of these are capable of reporting through a geostationary communications satellite. These observations will be entered into the national network for use in support of the NAS and the national weather network.

The New Generation Runway Visual Range (NRVR) program provides for a new generation RVR sub-element of the NAS. The NRVR provides runway visual range information to controllers and users in support of precision landing and take-off operations. The NRVR incorporates state-of-the-art sensor technology and embedded remote maintenance monitoring. The FAA plans to procure and install these NRVR systems at all new qualifying locations. FAA plans also call for the replacement of many existing RVRs in the NAS inventory.

The NRVR provides for near real-time measurement of visibility conditions along a runway (up to three points along the runway can be measured-- touchdown, midpoint, and roll-out) and reports these visibility conditions to air traffic controllers and other users. The system automatically collects and formats data from three sensors: a visibility sensor--forward scatter meters will replace the transmissometers currently in use; a runway light intensity monitor for both runway edges and center-line lights; and an ambient light sensor which controls computer calculations using a day or night algorithm. The data processing unit calculates runway visibility products and distributes the products to controllers and other users.

NRVR visibility sensors will be deployed at 308 airports. Delivery of the NRVR sensors began in November 1998. To date, 230 units have been delivered and 185 have been commissioned. At the current levels of annual funding, the program will be completed the deployment by the end of CY 2009.

The FAA procured the Operational and Supportability Implementation System (OASIS) to improve weather products, flight information, aeronautical data collection, analysis, and timeliness of dissemination, thereby enhancing the safety and efficiency of the NAS. OASIS will replace the Model-1 Full Capacity Flight Service Automation System, which includes the Aviation Weather Processor. OASIS will also integrate the Interim Graphic Weather Display System functions and include several automated flight service data handling capabilities. This configuration will be an initial deployment capability. Operational testing began in 1999; 16 systems have been deployed from the original plan of 61. Future enhancements leading to the full capability deployment will include: interactive alphanumeric and graphic weather briefings; direct user access terminal (DUAT) service functionality; automated special use airspace; and training support. OASIS will support flight planning, weather briefings, NOTAM service, search and rescue, and pilot access terminal services. Note: This program will be suspended in FY 2008.

The Next Generation Weather Radar (NEXRAD), known operationally as the Weather Surveillance Radar-1988 Doppler (WSR-88D), is a multi-agency program that defined, developed, and implemented the new weather radar. Field implementation began in 1990 and was completed in 1996. There are a total of 161 WSR-88D systems deployed. The FAA sponsored 12 systems in Alaska, Hawaii, and the Caribbean. DOC and DOD WSR-88Ds provide coverage over the continental U.S..

The FAA emphasized the development of WSR-88D algorithms that take advantage of the improved detection of precipitation, wind velocity, and hazardous storms. The FAA also stressed that these algorithms provide new or improved aviation-oriented products.

These improvements in detection of hazardous weather will reduce flight delays and improve flight planning services through aviation weather products related to wind, wind shear, thunderstorm detection, storm movement prediction, precipitation, hail, frontal activity, and mesocyclones and tornadoes. WSR-88D data provided to ATC through the WARP will increase aviation safety and fuel efficiency.

In addition, the three funding agencies support the field sites through the WSR-88D Radar Operations Center (ROC) at Norman, Oklahoma. The ROC provides software maintenance, operational troubleshooting, configuration control, and training. Planned product improvements include a shift to an open architecture, new antenna design, dual polarization, and the development of more algorithms associated with specific weather events, such as hurricanes.

The Air Route Surveillance Radar (ARSR-4) provides the ARTCCs with accurate multiple weather levels out to 200 nautical miles. The ARSR-4 is the first enroute radar with the ability to accurately report targets in weather. The ARSR-4 can provide weather information to supplement other sources. The ARSR-4 is a joint FAA/USAF funded project. Forty joint radar sites were installed during the 1992-1995 period.

The Weather and Radar Processor (WARP), has replaced the Meteorologists Weather Processor to provide aviation weather information to the Center Weather Service Units. WARP automatically creates unique, regional, WSR-88D-based, mosaic products, and sends these products, along with other time-critical weather information, to controllers through the Display System Replacement and to pilots via the FIS. WARP greatly enhances the dissemination of aviation weather information throughout the NAS. WARP underwent operational testing and evaluation in early FY 2003 and is operationally fielded at the 21 ARTCCs and the command center. Others systems used for enhancements, testing, and software support bring the total to 25 systems.

The Direct User Access Terminal (DUAT) system has been operational since February 1990. Through DUAT, pilots are able to access weather and NOTAMs and also file their IFR and/or VFR flight plans from their home or office personal computer.

AVIATION WEATHER COMMUNICATIONS

It should be noted that FAA communications systems are multi-purpose. Weather data, products, and information constitute a large percentage of the traffic, as do NOTAMS, flight plans, and other aeronautical data.

The National Airspace Data Interchange Network (NADIN II) packet-switched network was implemented to serve as the primary inter-facility data communications resource for a large community of NAS computer subsystems. The network design incorporates packet-switching technology into a highly connected backbone network which provides extremely high data flow capacity and efficiency to the network users. NADIN II consists of operational switching nodes at two network control centers (and nodes) at the National Aviation Weather Processing Facilities at Salt Lake City, Utah, and Atlanta, Georgia. It will interface directly to Weather Message Switching Center Replacement (WMSCR), WARP, ADAS, TMS, and the Consolidated NOTAM System. NADIN II also may be used as the intra-facility communications system between these (collocated) users during transition to end state.

The Weather Message Switching Center Replacement (WMSCR) replaced the Weather Message Switching Center (WMSC) located at FAA's National Communications Center (NATCOM), Kansas City, Missouri, with state-of-the-art technology. WMSCR performs all current alphanumeric weather data handling functions of the WMSC and the storage and distribution of NOTAMs. WMSCR will rely on NADIN for a majority of its communications support. The system will accommodate graphic data and function as the primary FAA gateway to the NWS National Centers for Environmental Prediction (NCEP)--the principal source of NWS products for the NAS.

To provide for geographic redundancy, the system has nodes in the NADIN buildings in Atlanta, Georgia, and Salt Lake City, Utah. Each node supports approximately one-half of the U.S. and will continuously exchange information with the other to ensure that both nodes have identical national databases. In the event of a nodal failure, the surviving node will assume responsibility for dissemination to the entire network.

Currently, specifications for an upgrade or replacement for the WMSCR are being formulated. The needs, when developed, will be entered into the AMS process for validation and acceptance into the NAS architecture.

The Flight Information Service (FIS) is a new communication system to provide weather information to pilots in the cockpit. FIS is a partnership program among the government and private industry with the government providing the base information and the bandwidth while the private companies provide the broadcast and value-added products. New products are screened for technical suitability and value to the pilots. Two companies have demonstrated preliminary products and capability.

The Worldwide Aeronautical Forecast System (WAFS) is a three geosynchronous satellite-based system for collecting and disseminating aviation weather information and products to/from domestic or international avia-

tion offices as well as in-flight aircraft. The information and products are prepared at designated offices in Washington, District of Columbia, and Bracknell, United Kingdom. The U.S. portion of WAFS is a joint project of the FAA and NWS to meet requirements of the ICAO member states. FAA funds the satellite communications link and the NWS provides the information/product stream.

Two of the three satellites are funded by the U.S.. The first is located over the western Atlantic with a footprint covering western Africa and Europe, the Atlantic Ocean, South America, and North America (except for the West Coast and Alaska). The second U.S.-funded satellite is positioned over the Pacific and covers the U.S. West Coast and Alaska, the Pacific Ocean, and the Pacific rim of Asia. The third satellite, operated by the United Kingdom, is stationed over the western Indian Ocean and covers the remaining areas of Europe, Asia, and Africa. The data available via WAFS include flight winds, observations, forecasts, SIGMETs, AIRMETs, and hazards to aviation including volcanic ash clouds.

The System Wide Information Manager is a new concept developed in conjunction with NGATS to support NAS operations in the 2025 timeframe. For all facets of the NAS operations, all data will be resident on a 'data cube' which will be accessible to all users; thus assuring that all users will have the same data. This will assure that collaborative decision making will benefit from the same situational awareness, weather and traffic programs.

AVIATION WEATHER RESEARCH PROGRAM

Working closely with the Integrated Product Team for Weather/Flight Services Systems, ATO sponsors research on specific aviation weather phenomena which are hazardous and/or limiting to aircraft operations. This research is performed through collaborative efforts with the National Science Foundation (NSF), NOAA, NASA, and the Massachusetts Institute of Technology's Lincoln Laboratory. A primary concern is the effective management of limited research, engineering, and development resources and their direct application to known deficiencies and technical enhancements.

IMPROVED AIRCRAFT ICING FORECASTS. The purpose of this initiative is to establish a comprehensive multi-year research and development effort to improve aircraft icing forecasts as described in the FAA Aircraft Icing Plan. The objectives of this plan are to develop: (1) an icing severity index, (2) icing guidance models, and (3) a better comprehension of synoptic and mesoscale conditions leading to in-flight icing. The result of this effort will be an improved icing forecasting capability that provides pilots with more timely and accurate forecasts of actual and expected icing areas by location, altitude, duration, and potential severity.

CONVECTIVE WEATHER FORECASTING. The purpose of this research effort is to establish more comprehensive knowledge of the conditions that trigger convection and thunderstorms and, in general, the dynamics of a thunderstorm's life cycle. The program will lead to enhanced capability to predict growth, areal extent, movement, and type of precipitation from thunderstorms. Gaining this forecast capability will allow better use of the airspace and help aircraft avoid areas with hazardous convective conditions (Figure 3-DOT-7).

MODEL DEVELOPMENT AND ENHANCEMENT. This research is aimed at developing or improving models to better characterize the state of the atmosphere and stratosphere in general, with specific emphasis on the flight operation environment specifically, with the aim to provide superior aviation weather products to end users.

AVIATION FORECAST AND QUALITY ASSURANCE.

The Product Development Team (PDT) for the Aviation Gridded Forecast System is working on the development of products for dissemination on the Aviation Digital Data System. New algorithms will be developed to present hazardous conditions in the flight operations environment. They will develop a process for automated production of the SIGMETs. There will be capability to assure quality and a real-time verification process.

WEATHER SUPPORT TO DEICING DECISION MAKING (WSDDM). This system develops products that provide forecasts on the intensity of snow and freezing rain, and how or when these phenomena will change in the short term. This information is needed by airport management to determine when an aircraft will require deicing before take-off. The water content of snow is believed to be an important factor. The output product is designed for non-meteorological aviation users and has been demonstrated at three different airports. Development work has been completed and FAA has made this system available to airport authorities who wish to use it as a decision aid.

CEILING AND VISIBILITY. A development and demonstration is underway in the San Francisco Bay area. The project will have unique sensors and the data will be used in new algorithms to develop improved forecasts. The project will continue over a number years as the progress is evaluated. This project is a joint effort with other Federal agencies and some of the effort is performed by academic researchers.

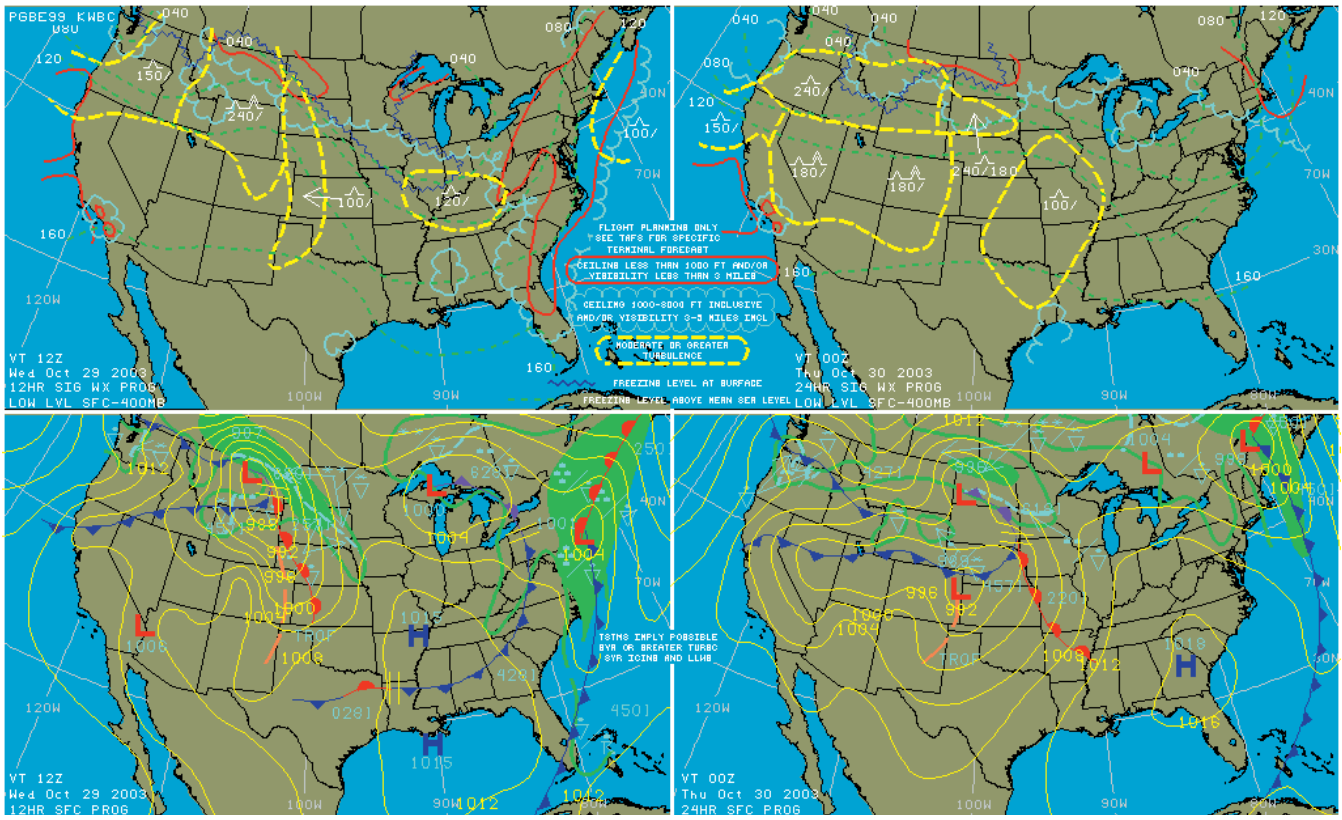


Figure 3-DOT-7. 4-panel Low Level Significant Weather graphics are produced by the Aviation Weather Center and accessible to pilots from their web site. (Source: AWC web site)

TURBULENCE. In addition to the work being performed by the JSAT under the Safer Skies Program, a PDT has a seven year plan to evaluate wind shear and turbulence around and on the approaches to Juneau, Alaska. Also, they are working with certain airlines to install instruments on aircraft with the capability to measure turbulence as sensed on the aircraft and report this information automatically. The data will be used to verify forecasts and to develop a standard index to report and warn for turbulence.

NEXRAD ENHANCEMENTS. Work is continuing to develop improvements to the existing products and to develop new graphic products. Hardware and software pre-planned product improvements are are being pursued. This is a joint effort among DOT, DOD, and DOC.

Under the auspices of the OFCM, FAA is investigating the possibilities of developing multi-use phased array radar to accomplish both weather surveillance and monitor aircraft movement in controlled airspace.

SPACE WEATHER. Space Weather is of concern to the FAA in several areas of operations and regulations. Ionospheric scintillation creates certain errors in the Global Positioning System that affects navigation, especially for instrument approaches to airports. In programs for Wide Area and Local Area Augmentation Systems (WAAS and LAAS) corrections for these effects are being developed. This will be a very important advance to promote the Free Flight management of the National Airspace System. In addition, the effects on the ionosphere have grave impacts on the use of high frequency communications which are essential in air traffic control of flights across the oceans and over the poles of the Earth.

FAA is embarking in research at the Civil Aeromedical Institute in Oklahoma City, OK, on the radiation effects on fetuses of newly pregnant women when flying at high altitudes and at high latitudes where exposure is increased. The exposure of flight crews to this hazard will be measured to determine if repeated flights in this regime may accumulate deleterious results.

FAA planners for commercial space operations are working on the weather requirements to set criteria for space launch activities. The commercial launch sites in California, Florida and Virginia are co-located with government sites where the weather support is available. However, at the new commercial space launch site in Kodiak, Alaska new criteria must be developed and established for standard procedures.

FEDERAL PROGRAMS IN SUPPORT OF ROAD WEATHER

THE ROAD WEATHER MANAGEMENT PROGRAM

The Federal Highway Administration (FHWA) coordinates a number of activities aimed at improving safety, mobility, productivity, environmental quality and national security on the nation's highways during weather threats. These activities include identification of weather impacts on the roadway environment, traffic flow, and the operational decisions that are made because of them. It includes research to advance the state of the art concerning road weather management tools, as well as documentation and promotion of the best practices. The FHWA acts through federal aid and national coordination since it does not operate the highway system or environmental observing systems that serve state and local highway operators, private road users, and the traveling public. FHWA activities are conducted as partnerships with other public agencies, the private sector, and universities.

As of 1997, coordination of FHWA weather related activities has been centered in the Road Weather Management Program (RWMP) within the FHWA's Office of Transportation Operations. From the beginning, an important goal of this program has been to help promote road weather research and development and this objective and its associated roadmap was further defined in 2005 by the passage of the *Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)*. Title V, Subtitle C - *Intelligent Transportation System Research*, Section 5308 of this bill contains specific reference to a "Road Weather Research and Development Program," the scope of which includes: maximizing the use of available road weather information and technologies; expanding road weather research and development efforts to enhance roadway safety, capacity, and efficiency; minimizing environmental impacts; and promoting technology transfer of effective road weather scientific and technological advances. The bill directs the Secretary of the USDOT to solely carry out research and development called for in the National Research Council's (NRC) report entitled, *Where the Weather Meets the Road, A Research Agenda for Improving Road Weather Services*. This effort includes: integrating existing observational networks and data management systems for road weather applications; improving weather modeling capabilities and forecast tools, such as the road surface and atmospheric interface; enhancing mechanisms for communicating road weather information to users (such as transportation officials and the public); and integrating road weather technologies into an information infrastructure. The bill also includes three guiding principles which are to: enable efficient technology transfer; improve education and training of road weather information users (such as state and local transportation officials and private sector transportation contractors); and coordinate with transportation weather research program in other modes, such as aviation.

Funding authorized for Section 5308 is $5.0 million per year for the years 2006 to 2009, and the Secretary was directed to give preference to applications with significant matching funds from non-Federal sources.

The FHWA Road Weather Management Program team is responsible for executing the program in coordination with the ITS Joint Program Office. The goals and objectives of the RWMP and its associated roadmap have been modified to align with the legislation, though such modification was minimal since the existing program already aligned very closely with the NRC report. Numerous efforts and initiatives within the RWMP are satisfying the requirements in the bill, including the Maintenance Decision Support System (MDSS), the *Clarus* initiative, and the Memorandum of Understanding between the FHWA and NOAA.

Some of the activities occurring within the RWMP include:

THE STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP)

Congress established the Strategic Highway Research Program (SHRP) under the 1987 Surface Transportation Act. SHRP examined a number of different subject areas including winter maintenance operations on the nations highways. The research program was active until 1993, producing specifications, testing methods, equipment, and advanced technologies. Following the success of the five-year effort, the FHWA coordinated a national program, entitled SHRP Implementation, to work with state and local highway agencies to implement and evaluate the products. The American Association of State Highway and Transportation Officials (AASHTO), and the Transportation Research Board (TRB) administered this program in coordination with FHWA. The SHRP Implementation web site (www4.trb.org/trb/dive.nsf/web/shrp_implementation) contains information on the SHRP Lead States Program, SHRP products under evaluation and implementation, and SHRP in general.

THE INTELLIGENT TRANSPORTATION SYSTEMS (ITS) PROGRAM

The Intermodal Surface Transportation Efficiency Act of 1991, established the ITS Program, including its research program that funds the FHWA Road Weather Management Program activities. This program is overseen by the ITS Joint Program Office (ITS-JPO), which is a cross-modal office

hosted in the USDOT's Research and Innovative Technology Administration. While ITS initially focused on automated highways and metropolitan areas, a rural focus was initiated in 1996. The rural ITS program identified maintenance and weather as additional ITS focus areas, and recognized the need for total integration of the maintenance, traffic, and emergency management functions across wide areas and between states. The following research activities are examples that fall within this overall weather-across-ITS strategy:

Vehicle Infrastructure Integration (VII) Initiative

This initiative (www.its.dot.gov /vii/index.htm) is exploring the potential of creating a data sharing communication system that could support vehicle-to-vehicle and vehicle-to-infrastructure communications. The system, once implemented, will provide real-time travel and weather information to both the public sector and private industry, and also support advanced safety applications. VII could be a significant enabler of weather-related applications, such as vehicle-based sensors that gather environmental data system-wide. The resulting communications network would allow weather, traffic and other information to be transmitted to transportation operators, providing a real-time view of the conditions on every major road within the transportation network. Such concepts will be explored as the initiative matures. The functional architecture and requirements for VII are under development. Preliminary documentation describes some of the weather-related data items that could be directly measured or inferred from vehicle sensor systems including precipitation detection, ambient air temperature, fog or visibility information, and road traction state or mobility.

National ITS Architecture and ITS Standards

Intelligent Transportation Systems use open system principles and are based upon the National ITS Architecture - a modularly defined set of information processes with known protocols for exchanging information between modules. While road weather information was not an original focus of the National ITS Architecture, it has since been captured through the Maintenance and Construction Operations (MCO) user service. MCO development included the definition of a Road Weather Information Service terminator designed to complement the existing Weather Service terminator. Together, these represent the division of responsibility for road weather information, provided largely by private vendors and based on ESS observations, and weather information in general. The interfaces between the two types of services are then defined as being outside of the ITS, although the FHWA continues to maintain an active interest in their development.

It is hoped that further detailing of weather applications in traffic and emergency management will lead to further architecture developments in the years ahead. As the interface between the ITS and evolving national weather information systems becomes better defined, the National ITS Architecture and standards will provide a technical basis for integration and promotion of open system principles. Version 5.1 of the National ITS Architecture can be found at http://itsarch.iteris.com/itsarch/.

Environmental Observing Systems

Over 2,400 ESS are owned by state transportation agencies in the United States as shown in Figure 3-DOT-8. More than 2,000 of these ESS are field components of the Road Weather Information Systems. ESS placed in the field are generally fixed, with in situ sensors for the usual atmospheric weather variables, as well as pavement and subsurface temperature probes, pavement chemical concentration or pavement freezing point. In some cases, and potentially over all road mileage, mobile environmental sensors are being deployed to observe weather and pavement conditions from vehicles. An important application of the mobile, and potentially remote, sensing is thermal mapping of road segments. This technique provides snapshots of complete pavement temperature profiles and is used both to select fixed ESS sites and to spatially predict temperatures based on time series predictors at the fixed stations. FHWA-funded research is also investigating the potential to extract surface weather and road condition data from standard traffic camera imagery. The potential value of this research is significant considering the fact that in 2004, there were already 4000 Closed Circuit Television (CCTV) traffic cameras deployed nationwide.

At present, ESS data across the United States are neither integrated nor open. The data are not centrally collected, in a standard format, available to all users, nor uniformly used. A USDOT-sponsored initiative entitled *Clarus* aims to correct this shortfall by designing and demonstrating an integrated road weather observational network, and establishing a partnership to facilitate deployment of a nationwide surface transportation weather observing system. The long-term vision of *Clarus* is that all data from state DOT ESS will be routinely collected, quality-checked, and translated into an open standard format. Quality checking algorithms and direct feedback to state DOT points of contact will improve agency awareness of sensor status. Access to robust and calibrated data will be provided through an open Internet data portal. The *Clarus Concept Of Operations* and the *Clarus* system design has been completed. A Proof-of-Concept demonstration occurred in 2006, and regional demon-

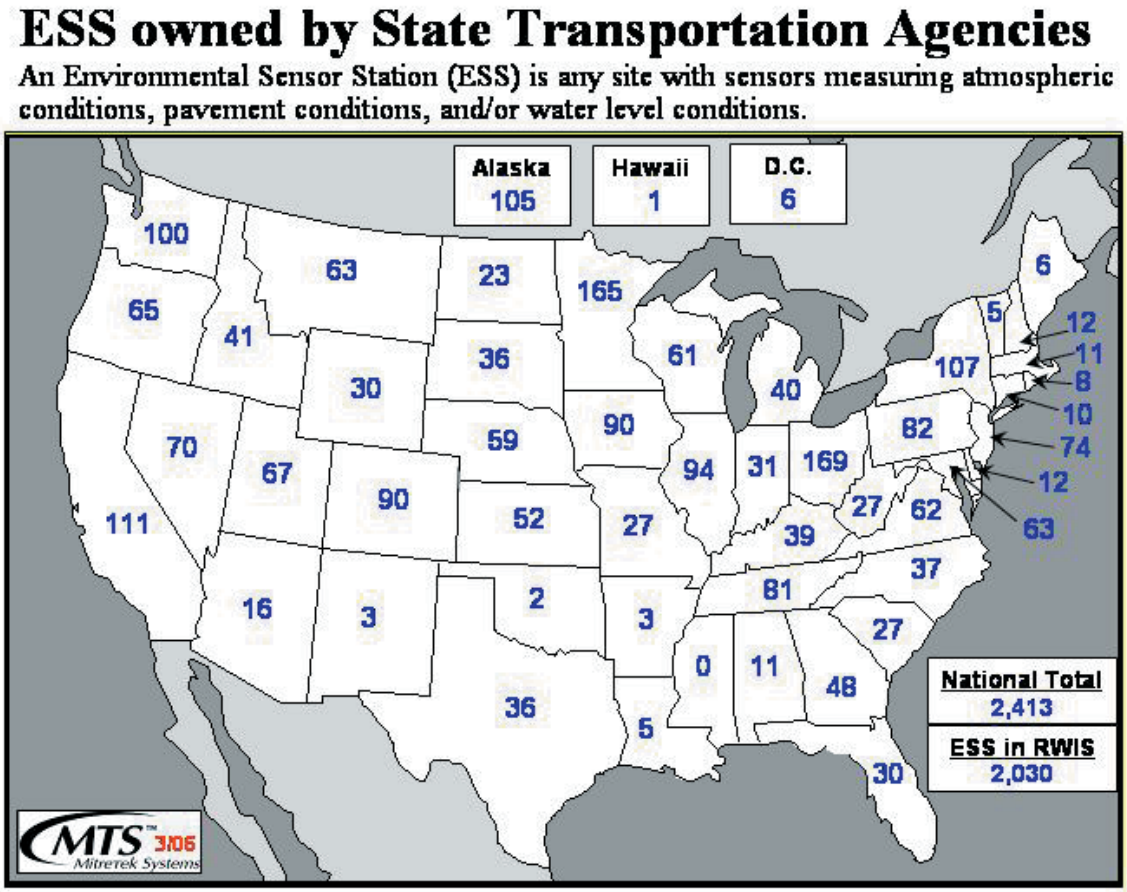


Figure 3-DOT-8. Census of deployed Environment Sensor Station (ESS) units. An ESS is a site measuring atmospheric, pavement and/or water level conditions. Many state transportation agencies deploy ESS as field components of Road Weather Information Systems (RWIS). As shown on the map, there are over 2,400 ESS owned by state transportation agencies. Most of these stations (i.e., 2,000) are part of RWIS and used to support road maintenance activities. The other environmental sensor stations are deployed for various applications including flood monitoring and aviation.

strations are planned for 2007.

In order to address some of the issues related to surface weather observations, the FHWA is participating in several OFCM projects including the Weather Information for Surface Transportation Working Group, the Phased Array Radar (PAR) Joint Action Group, the Joint Action Group for Joint Urban Test Beds (JAG/JUTB), the Fire-Weather Joint Action Group, the Committee on Environmental Information Systems and Communication, and the Committee for Environmental Services, Operations, and Research Needs (CESORN). FHWA is also participating in NOAA efforts to explore the modernization of the cooperative observer network and development of a national surface weather observing system.

From 2001 to 2003, the FHWA sponsored five research projects, under the Cooperative Program for Meteorological Education and Training (COMET) (www.comet.ucar.edu), which became the first to add state DOTs to the traditional partnerships of NWS forecast offices and universities. The COMET projects in Iowa, Nevada, New York, Pennsylvania, and Utah fostered the sharing of environmental data and facilitated advanced meteorological modeling to enhance road weather forecasts. Ultimately, these efforts will contribute to the development of decision support tools for winter maintenance managers, traffic managers, and the traveling public. Lessons learned from these projects can help all state DOTs better manage RWIS networks and achieve maximum utility from RWIS data.

In order to enhance observation capabilities and define requirements for road weather observing systems, the Road Weather Management Program worked with the Aurora Pooled Fund Program and the AASHTO Snow and Ice Cooperative Program to produce the *Road Weather Information System ESS Siting Guidelines* (http://ops.fhwa.dot.gov/publications/ess05/). The guidelines, published in 2005, provide a set of recommendations to support uniform siting of ESS that collect road and weather observations for RWIS, and are intended to improve the usefulness of road weather information derived from these observations. The Road Weather Management Program will facilitate the adoption and implementation of the guide-

lines in transportation agencies through targeted research and deployment activities.

Decision Support

Transportation system managers and users identified three critical surface weather information requirements as the trinity of "relevance, accuracy and timeliness". Although significant progress continues to be made by both the public and private sectors in providing new technologies to meet these requirements, a significant gap has developed between the amount of increasingly good and plentiful surface weather information, and the amount of support available for effective operational decision-making. Assisting and supporting the research and development of ways to overcome this gap has become an important initiative within the FHWA.

Decision support is where surface weather data needs to be customized since each operational decision is specific to a type of road weather management strategy, a particular place and time, and the characteristics of the decision maker (their expertise, their location, their information processing equipment). Road weather management strategies mitigate weather impacts by advising motorists of prevailing and predicted conditions (e.g., traveler information), controlling traffic flow and roadway capacity (e.g., weather-responsive traffic signal timing, road closure), and/or treating roads to minimize or eliminate weather threats (e.g., plowing, anti-icing/deicing).

In 1999 and 2000, decision support requirements, first generally and then specifically for winter road maintenance, were studied in the Surface Transportation Weather Decision Support Requirements (STWDSR) project. This project used weather threat scenarios to identify specific decisions made in winter road maintenance, their timing, and the expected confidence of the decisions at various time horizons. General requirements for emergency managers, traffic managers, and road users were also defined. The STWDSR project became an important contributor to the OFCM's *Weather Information for Surface Transportation (WIST)* needs analysis, the National ITS Architecture modifications, and to the Maintenance Decision Support System (MDSS) prototype project.

Along with the Maintenance Decision Support System described below, in 2006 FHWA and the Missouri DOT developed and tested a prototype Weather Response System (WRS) for transportation system operations. The WRS was intended to use road weather information from the NWS, the private sector, state agencies and other sources to support transportation control, maintenance and operations decision-making. The results of the test and evaluation will be used to improve the prototype and bring it closer to statewide deployment.

Support for Maintenance Managers

The Maintenance Decision Support System (MDSS) project is a multi-year, FHWA-sponsored effort that was envisioned to assist transportation managers and operators improve roadway levels of service during winter weather events while minimizing road treatment costs (e.g., by optimizing use of labor, materials, and equipment). This data management tool has an ensemble of advanced weather prediction and road condition prediction capabilities, including air and pavement temperatures, precipitation start/stop times, precipitation types and accumulation amounts. These predictions are fused with customized winter road maintenance rules of practice to generate route-specific treatment recommendations (i.e., strategy, timing, and material application rates).

In the spring of 2003, the first functional MDSS prototype was demonstrated and evaluated by three Iowa DOT maintenance garages. The main display of the demonstration prototype, shown in Figure 3-DOT-9, includes predicted weather and road conditions, a weather parameter selection menu, a map of roads and weather alerts, as well as forecast animation controls. During the winter of 2004-2005, the demonstration domain was moved to Colorado to assess prototype capabilities over more complex terrain. Based on lessons learned from the preliminary demonstration in Iowa, the subsequent releases of Versions 2.0 and 3.0 in 2003 and 2004 respectively, and the Colorado demonstration, Version 4.0 was made available in November 2005.

Lessons learned, recommended enhancements and the future directions of the program were addressed and discussed during the 8th annual stakeholder meeting that was held in Falls Church, Virginia in August 2006.

The MDSS development process has moved forward to the point where the AASHTO Technology Implementation Group (TIG) proclaimed it to be a "2006 ready-to-implement technology" (AASHTO Journal 4/7/2006). Such a designation by one of FHWA primary partners will significantly support the deployment of MDSS. In addition, FHWA and its partners have worked together to see the MDSS project evolve from prototype development to proactive outreach, deployment assistance, technology transfer, and expansion of the functionality to other applications, such as summer maintenance and traffic management, and even other surface transportation sectors. This change is consistent with the FHWA's original deployment strategy, which included creating an environment that enables the private sector to build end-to-end products using core MDSS prototype functionality/technology as their foundation. These products will be procured by public agencies (e.g., state DOTs), enabling both the private and public sectors to benefit from millions of dollars of

high-risk research. One example of technology transfer is the MDSS Pooled Fund Study (PFS) project led by the South Dakota DOT. Other participants include the state DOTs in Colorado, Indiana, Iowa, Minnesota, Kansas, Wyoming, New Hampshire and North Dakota, as well as Aurora (a pooled fund research program), a private vendor, and the FHWA. The objective of the project has been to build, evaluate, and deploy an operational MDSS by refining model components and conducting extensive field tests.

An example of proactive outreach has been the development and deployment of the "MDSS Road Show" by the FHWA Resource Center. This free seminar, which includes both an Executive Briefing and a Shop Session, is available to transportation managers, maintenance engineers and operators. The presentation describes the functions of MDSS, its capabilities, and its limitations. It also provides a level of detail that helps public agencies make more informed decisions about investing in such a tool.

Other FHWA-sponsored support activities planned for 2007 include: updating several components of the MDSS core system; overseeing the release of an enhanced version of the software; and conducting several cost/benefit analyses to generate quantitative results that can be used by the transportation community to justify investments in MDSS. Additional information on the MDSS project and the Road Show can be found at www.rap.ucar.edu/projects/rdwx_mdss and at http://ops.fhwa.dot.gov/Weather/index.asp.

Support for Traffic Managers

In 2006, the Road Weather Management Program developed a 5-year roadmap for Weather-Responsive Traffic Management. The roadmap identifies the goals and activities that FHWA will pursue in three major program areas: data collection and integration, impacts of weather on traffic flow, and traffic management strategies. The roadmap also serves as the basis for future work to identify, develop, test, and evaluate a variety of weather-responsive traffic management strategies.

Empirical studies of traffic flow and driver behavior during inclement weather are currently underway and will be completed in 2007. The Road Weather Management Program is working with FHWA's Office of Operations Research and Development to collect empirical traffic, weather, and pavement condition data on both freeway and arterial routes to quantify weather impacts on driver behavior, traffic speeds, traffic volumes, and travel time delay. This research will improve the understanding of how traffic flow and driver behavior change under adverse weather conditions. Once these factors are better understood, the information can be incorporated into traffic simulation models and, ultimately, traffic information and control tools.

511-The National Traveler Information Telephone Number

Based on the concept that a standardized number for travel information would be beneficial to the traveling public, a broad coalition of ITS interests worked together to allocate a national 511 traveler information telephone number. In 2002, the FHWA sponsored a number of grants to plan for state deployment of 511 services, and guidelines were issued on service content. A survey on traveler information conducted by ITS America indicated that weather and road condition information were highest in demand by travelers, and therefore, this type of information is considered a key component of 511 services. The means of delivering information through 511 are still being developed, including ways to serve peak demands for emergency evacuation information, as part of the homeland defense, or other threat capability.

In June 2003, the 511 Deployment Coalition released a *Deployment Assistance Report, Weather and Environmental Content on 511 Systems,* to recommend basic content and provide for consistency in 511 systems as they are deployed across the country. Since these systems are in their infancy, gaps exist in defining the types of road weather information travelers' desire, appropriate data formats, and the frequency and detail needed for travelers to make safe and effective decisions. The Road Weather Management Program has participated in several 511 Deployment conferences, including the one held in San Diego, California in July 2006, and continues its efforts to help establish road weather data requirements and close these gaps. The 511 program must also find ways to complement NOAA Weather Radio broadcasts, and use the NWS official watches and warning information. The 511 capability is just one more way in which ITS is becoming a significant dissemination means for road weather information. As of May 2006, 511 services were operational in 22 states, available to 32 percent of the population, and expected to be launched in eight more states by the end of the year (Figure 3-DOT-10).

Weather Impacts on Roadway Safety, Mobility & Productivity

While the impacts and associated costs of adverse weather on surface transportation are considered to be immense, it has been difficult to quantify specific costs related to these impacts. This is also true of the benefits (as avoidable costs) that are achieved through better information that helps support more effective responses and/or mitigation strategies. It is likely that the costs to mobility, in terms of delay due to weather, are the most significant part of this economic picture. For example, initial estimates of the economic impact of weather-related delay on trucks in the 20 major

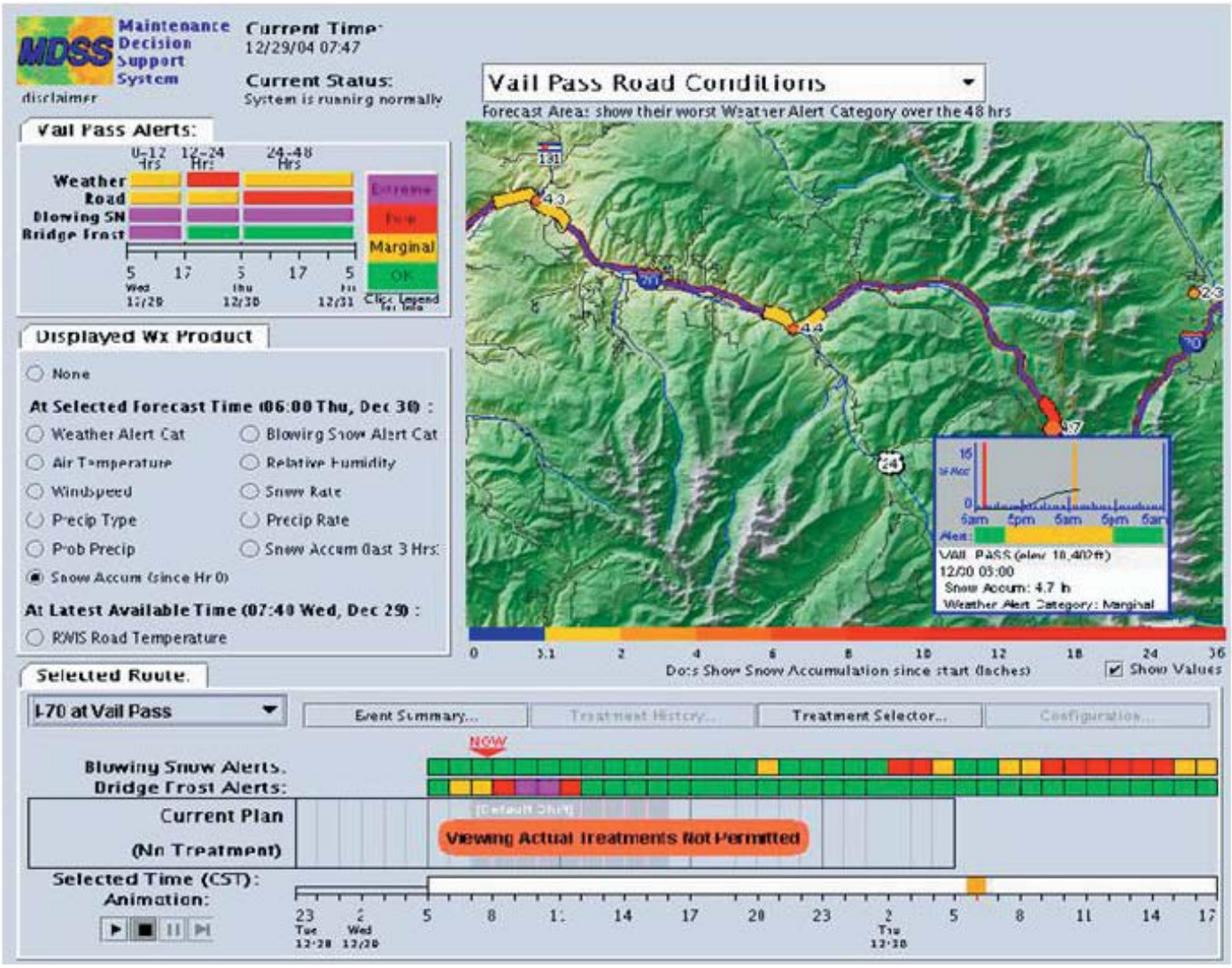


Figure 3-DOT-9 . Schematic of FHWA's Maintenance Decision Support System.

metropolitan areas most affected by adverse weather are on the order of $2 billion per year.

In an attempt to get a better understanding on the relationship between adverse weather and traffic delays, the FHWA sponsored a series of analyses that were conducted for the Seattle, Washington and Washington, DC metropolitan areas. These analyses combined surface weather observations with traffic speed data, both empirical and modeled. The results were consistent in showing about a 12 percent increase in travel time averaged over a wide range of weather events. A second analysis of delay effects in Washington, DC was conducted with archived Doppler radar data for more precise and more dynamic inference of road weather conditions. Analysis results indicated that during peak travel periods, travel time increased by roughly 24 percent when precipitation was present. It is the FHWA's belief, that achieving a better understanding of weather-traffic interactions, will lead to an improved ability to mitigate the impact of weather-related delays through traffic management practices, including speed management, access control (e.g., road closure), motorist warning systems, and weather-responsive signal timing.

Road Weather Management Program Outreach and Training

The Road Weather Management Program web site (http://www.ops.fhwa.dot.gov/Weather/index.asp) contains a wealth of information on the program. This includes material objectives and initiatives, weather impacts, benefits of road weather management strategies, technologies to help mitigate weather impacts, best practices, training, upcoming events, a listing of over 200 road weather related publications, and 30 case studies of road weather management systems. Each case study has six sections including a general description of the system, system components, operational procedures, resulting transportation outcomes (i.e., improved safety, mobility and/or productivity), implementation issues, as well as contact information and references.

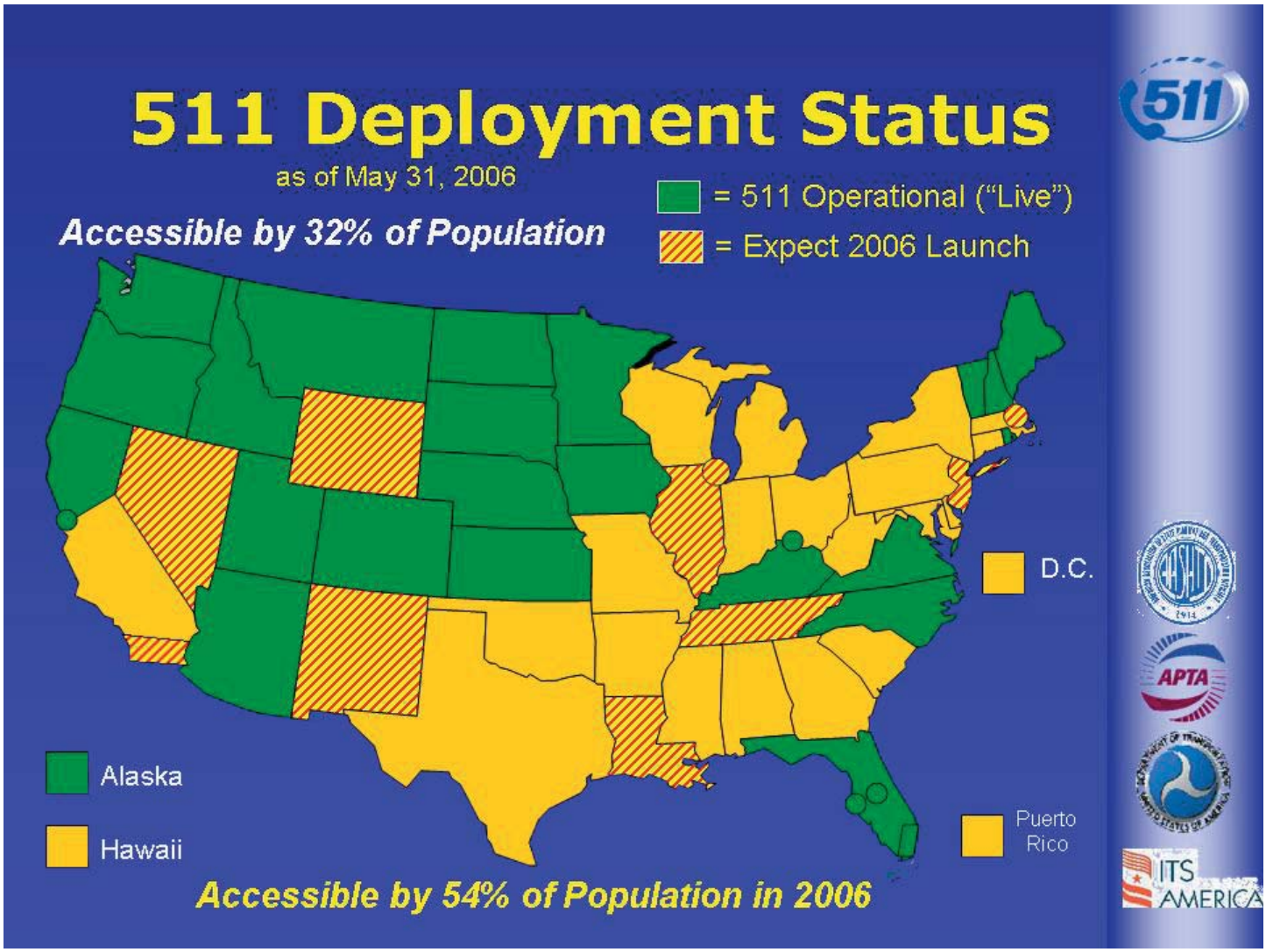


Figure 3-DOT-10 . 511 National Traveler Information Telephone Number Deployment - May 2006.

A key outreach activity of the program is the annual *Eastern Winter Road Maintenance Symposium & Equipment Expo* (or *Snow Expo*). Over the past eleven years, FHWA has partnered with state agencies to host the *Snow Expo*, which provides a forum for sharing information and technologies used to counter the effects of winter weather. AASHTO is now the lead sponsor, with FHWA as a co-sponsor. More information on the *Snow Expo* can be found at www.easternsnowexpo.org.

The FHWA sponsors training programs and conducts outreach to promote Road Weather Management Program products and activities. In 2005, a one-day training course on *Principles and Tools for Road Weather Management* became available through the National Highway Institute (NHI course No. 137030A). The course is aimed at helping those involved in highway maintenance and operations develop techniques and strategies for tackling road weather problems. The course will provide basic knowledge of meteorology and address the technological resources available to support highway personnel in making effective road weather management decisions. Additional details are listed on National Highway Institute web site (www.nhi.fhwa.dot.gov).

The computer-based *Anti-Icing/RWIS Training Program* is a comprehensive, interactive training program for winter operations that was jointly developed by AASHTO, with support from FHWA and Aurora. The training program covers an introduction to anti-icing and winter maintenance, winter road maintenance management, winter roadway hazards and principles of overcoming them, weather basics, weather and roadway monitoring for anti-icing decisions, computer access to road weather information, and anti-icing practice in winter maintenance operations.

The Federal Railroad Administration (FRA) supports improving the collection, dissemination, and application of weather data to enhance railroad safety through the Intelligent Weather Systems project, as part of the Intelligent Railroad Systems and Railroad System Safety research programs. These programs address safety issues for freight, commuter, intercity passenger, and high-speed passenger railroads.

Intelligent weather systems for railroad operations consist of networks of local weather sensors and instrumentation - both wayside and on-board locomotives - combined with national, regional, and local forecast data to alert train control centers, train crews, and maintenance crews of actual or potential hazardous weather conditions. Intelligent weather systems will provide advance warning of weather caused hazards such as flooding; track washouts; snow, mud, or rock slides; high winds; fog; high track-buckling risk; or other conditions which require adjustment to train operations or action by maintenance personnel (Figure 3-DOT-11).

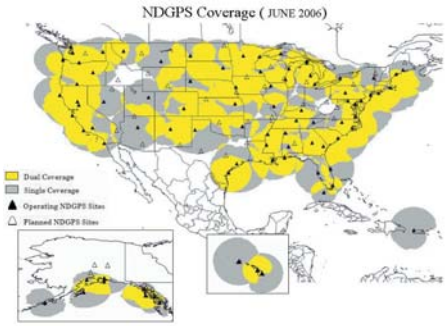
Figure 3-DOT-11. Track washed out by flood waters from Hurricane Alberto.

Weather data collected on the railroad could also be forwarded to weather forecasting centers to augment their other data sources. The installation of the digital data link communications network is a prerequisite for this activity.

FRA intends to examine ways that weather data can be collected on railroads and moved to forecasters, and ways that forecasts and current weather information can be moved to railroad control centers and train and maintenance crews to avoid potential accident situations. This is one of the partnership initiatives identified in the National Science and Technology Council's *National Transportation Technology Plan*.

WEATHER FORECASTING ENHANCED BY NATIONWIDE DIFFERENTIAL GLOBAL POSITIONING SYSTEMS (NDGPS)

Nationwide Differential Global Positioning System (NDGPS) is a system of reference stations that monitors GPS and broadcasts corrections, which can be used by the GPS receiver to improve the accuracy, integrity and availability of the GPS position.



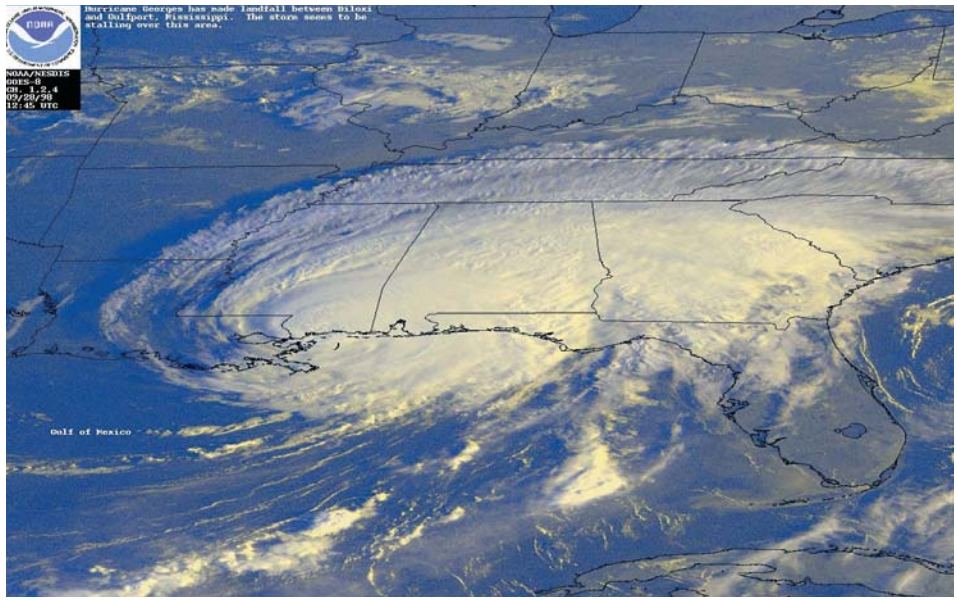
NDGPS is used in a myriad of applications including: maritime navigation, positive train control, precision farming, dredging, graphic information systems and surveying.

The Global Systems Division (GSD) of the Earth System Research Laboratory (ESRL) in the National Oceanic and Atmospheric Administration (NOAA) developed a unique application, which very accurately measures the amount of water vapor in the atmosphere by taking advantage of the dual-frequencies, reference station

receivers at the NDGPS sites and a suite of weather sensors added to each reference station. The weather sensors, circled in the photo above, measure temperature, relative humidity and barometric pressure. The GPS satellites broadcast on two frequencies, L1 and L2. GSD uses these two frequencies to correct for the ionospheric delay that is caused by changes in the refractive index associated with the concentration of free electrons in the upper atmosphere. The ionospheric delay is usually about 6-10 times greater than the signal delay caused by the neutral, non-electrically conducting, atmosphere. GSD can than estimate the signal delays caused by the neutral atmosphere by comparing the errors in position between sites that are over 500 km apart by viewing the same satellites for about 30 minutes. Most of the delay in the troposphere (lower atmosphere) is caused by the mass of the atmosphere, or the hydrostatic component, while the induced dipole moment of the water vapor molecules

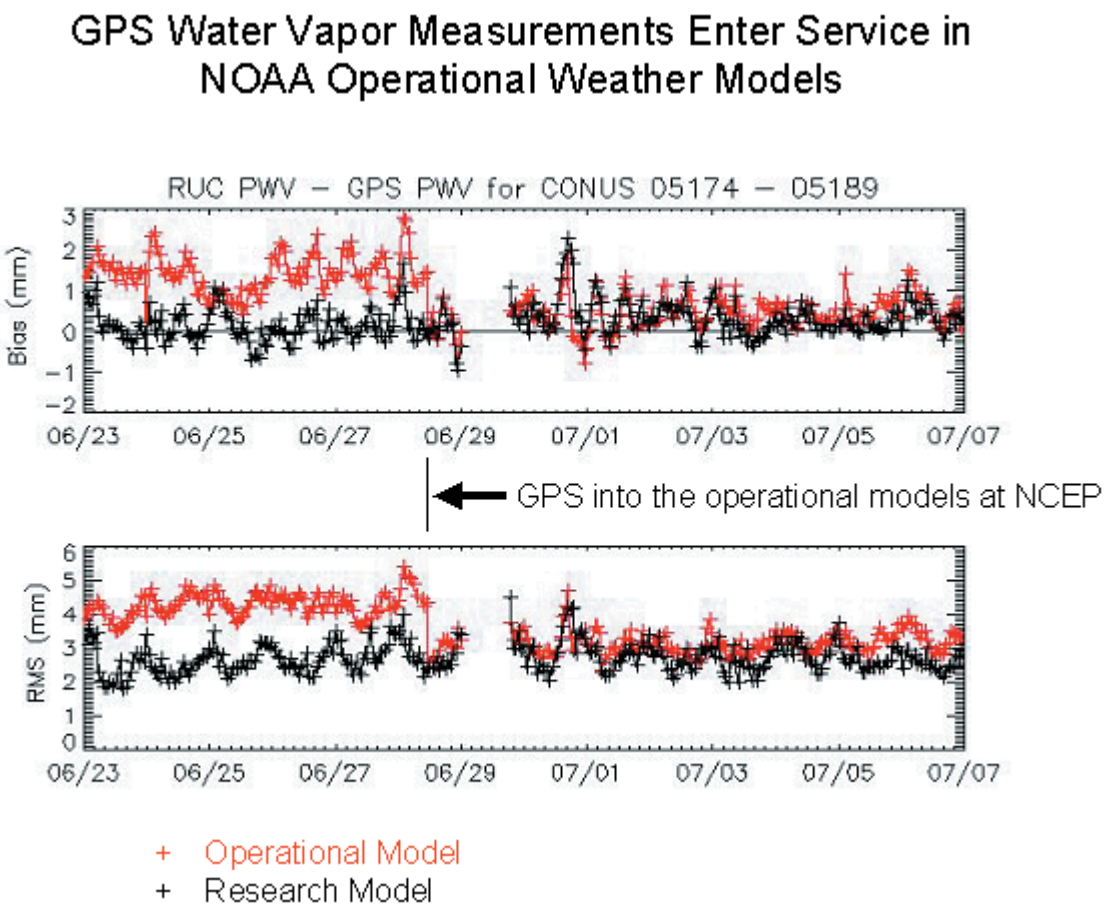
in the atmosphere is responsible for the rest of the delay.

The GSD can accurately estimate the hydrostatic delay by putting a pressure sensor at the NDGPS site and mapping the surface pressure into signal delay using well-known physical relationships. Subtracting the hydrostatic delay from the observed tropospheric delay gives the wet signal delay caused by water vapor in the atmosphere. Then, the wet delay is mapped into the quantity of water vapor responsible for the delay using information about the temperature of the atmosphere and the characteristics of the air at microwave frequencies.



This results in the equivalent height of a column of water that would form if all of the water vapor in the atmosphere were to fall or precipitate. The total precipitable water vapor content is a direct measure of how much raw material is in the atmosphere in the form of rain, snow, hail and clouds. As the water vapor changes state from gas to liquid to solid and back again, it releases or absorbs energy associated with the latent heat bound-up in the molecules. This energy release and absorption is the primary energy responsible for weather. The reason that water vapor is hard to measure is that it only manifests itself when it changes state, and most instruments that can observe water in its gaseous state do not work well under all weather conditions. However, NDGPS works remarkably well in all weather conditions.

Water vapor is the most important



component of weather and the least observed. In June 2005, the research and development program to evaluate the use of NDGPS data became an operational program feeding near-real time date into NOAA's operational models. The addition of this data has greatly improved the model and short-term weather forecasts, especially during periods of active weather such as fronts, hurricanes or tornadoes.

The Federal Railroad Administration will continue to work with NOAA's GSD and the Coast Guard to install weather sensor systems at all of the NDGPS sites as they are built.

NATIONWIDE SURFACE TRANSPORTATION WEATHER OBSERVING AND FORECASTING SYSTEM - *CLARUS*

The weather products available today through both public and private resources are typically insufficient to meet the demands of transportation operations. Nearly all weather forecasting today is based on observations of the atmosphere. However, the greatest impact of weather events on the safety and mobility of travelers and freight occurs on the surface. Many state DOT's have invested in road weather information systems that provide their agencies with observations on conditions at the surface and just below the surface. Other entities such as agriculture, water districts, electric utilities, and railroads also operate weather observation stations. FRA is developing a partnership with the Federal Highways Administration (FHWA), state DOT's, NOAA and others to establish a nationwide road weather observation network known as *Clarus*. The goal of the *Clarus* project is to tie this mosaic of private and public observation stations into a cohesive weather forecasting system that is specifically focused on surface conditions.

DEPARTMENT OF AGRICULTURE WEATHER PROGRAMS

The Nation's food and fiber products are a critical resource impacting our domestic and international economic situation and are essential for ensuring our national security and shaping foreign policy. Weather is the most important factor influencing the Nation's variability in crop yields and related production. The United States Department of Agriculture (USDA) monitors global weather and agricultural developments through the Joint Agricultural Weather Facility (JAWF). The JAWF provides critical information to decision-makers formulating crop production forecasts, programs that provide natural disaster assistance to U.S. farmers and ranchers, emergency relief programs, and trade policy. USDA operates specialized weather observing networks such as SNOTEL, SCAN, and RAWS that provide vital data and information used to forecast seasonal water supplies in the West, to support national conservation programs, and to monitor the health of the Nation's forests. USDA conducts supporting research that focuses on understanding the interactions of weather and climate with plants, animals, forests, and forest ecological systems.

Numerous agencies within the U.S. Department of Agriculture (USDA) require a wide range of high quality weather and climatological data to successfully carry out their missions. Some of the diverse applications that require accurate, timely, and comprehensive data include crop monitoring and weather impact assessment, agricultural yield and productivity modeling, natural resource conservation planning, forest fire potential monitoring, irrigation scheduling, water supply information, reinsurance and compliance programs, crop disaster assistance and emergency relief programs, integrated past management, crop yield modeling, and agricultural research studies. The following is a brief description of agency weather activities.

OFFICE OF THE CHIEF ECONOMIST /WORLD AGRICULTURAL OUTLOOK BOARD

The World Agricultural Outlook Board (WAOB) is located within the Office of the Chief Economist (OCE). The WAOB's primary objectives are consistency, objectivity, and reliability of outlook and situation related material, including weather information developed within the USDA. The WAOB coordinates all weather and climate information and monitoring activities within USDA. The WAOB also manages the Joint Agricultural Weather Facility (JAWF), which serves as the focal point in the USDA for weather and climate information and impact assessment.

THE JAWF was created in 1978 as an operational unit, and is jointly managed by the USDA/OCE/WAOB and the U.S. Department of Commerce (DOC)/National Oceanic and Atmospheric Administration (NOAA)/ National Weather Service (NWS)/National Centers for Environmental Prediction (NCEP)/Climate Prediction Center (CPC). The primary mission of the JAWF is to routinely collect global weather data and agricultural information to assess the impact of growing season weather conditions on crops and livestock production prospects. JAWF meteorologists work as a team, monitoring global weather conditions and crop developments on a daily basis, and preparing real-time agricultural assessments (Figure 3-USDA-1). These assessments keep USDA commodity analysts, the OCE, and the Secretary of Agriculture and top staff informed of worldwide weather related develop-

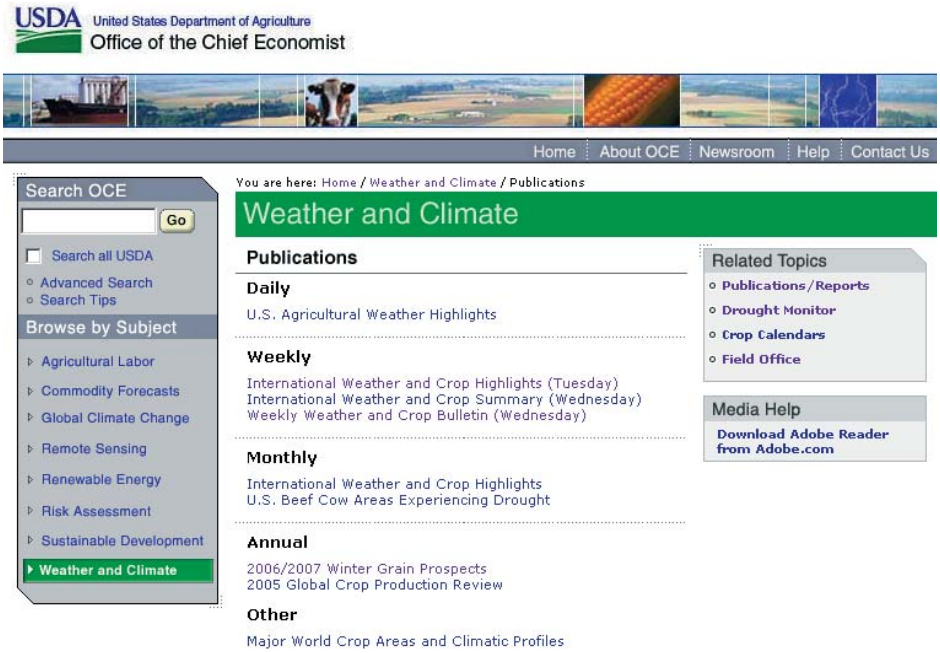


Figure 3-USDA-1. Joint Agricultural Weather Facility Web Site.

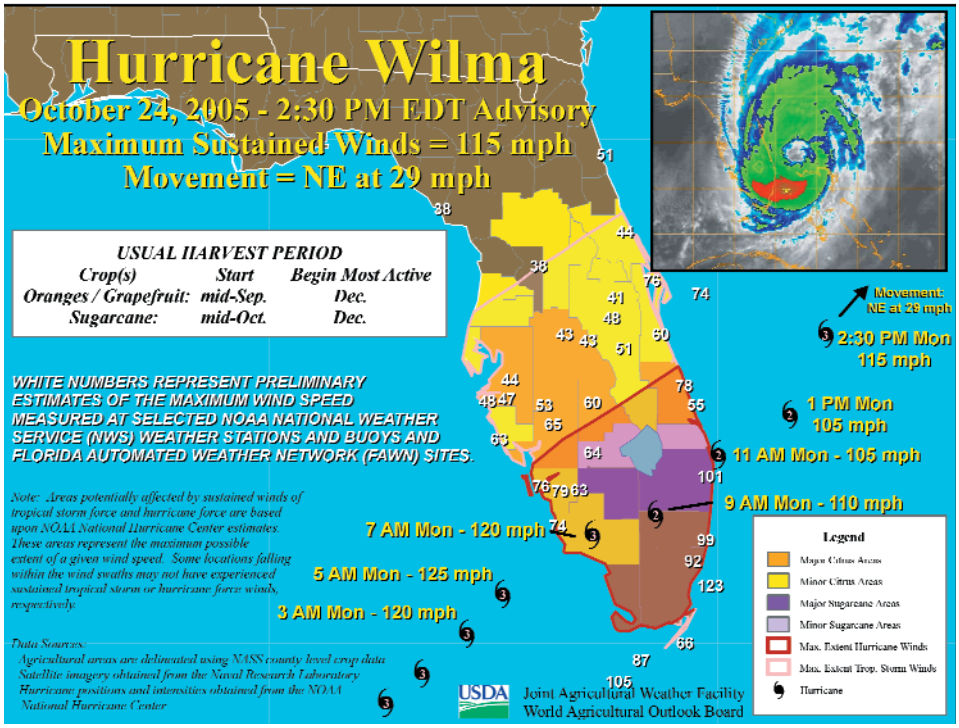


Figure 3-USDA-2. Special agricultural assessment example - Hurricane Wilma.

ments and their effects on crops and livestock. In addition to providing routine assessments, OCE/WAOB agricultural meteorologists at JAWF are frequently requested to prepare special assessments when adverse or anomalous weather conditions (i.e., droughts, heat waves, freezes, floods, and hurricanes) are observed in major crop producing regions. An example of an assessment made during Hurricane Wilma is shown in Figure 3-USDA-2. This special assessment was prepared using sophisticated GIS tools, overlaying the track and sustained wind speeds of the hurricane over Florida citrus and sugarcane producing areas. When integrated with economic analyses and information, these routine and special crop-weather assessments provide critical information to decision-makers formulating crop production forecasts, trade policy, and disaster relief. They also help identify potential agricultural markets for U.S. products around the world. Inputs from OCE/WAOB/JAWF are integrated into USDA's monthly foreign crop production estimates. Weekly briefings on global weather and crop developments are provided to USDA top staff. The Senate and House Agricultural Committees periodically request agricultural weather briefings that focus on the severity and impact of drought, heat waves, and excessive wetness in major crop areas across the Nation.

The JAWF serves as the USDA focal point for weather data received from the Global Observing System, a worldwide network of over 7,000 meteorological reporting stations managed by the World Meteorological Organization (WMO). These data are used at JAWF and other USDA agencies for a number of agricultural applications. The agricultural meteorologists of OCE/WAOB/JAWF merge these weather data with climatological analyses and global agronomic data, to determine the weather's impact on crop development and yield potential. A major source of domestic weather and climate data that are used in crop and weather analyses by JAWF comes from the NWS's Cooperative Observer (COOP) Network.

JAWF's flagship publication is the *Weekly Weather and Crop Bulletin (WWCB)*. The WWCB is jointly produced by USDA/OCE/WAOB, USDA/National Agricultural Statistics Service (NASS), and the DOC/NOAA/NWS/NCEP/CPC. First published in 1872 as the *Weekly Weather Chronicle*, the publication has evolved over the past 134 years into one that provides a vital source of information on weather, climate, and agricultural developments worldwide. The publication is a shining example of how two major departments (USDA and DOC) within the Federal government can mutually cooperate, combining meteorology and agriculture expertise to provide a service that benefits the economic well being of the nation. The *WWCB* (Figure 3-USDA-3) highlights weekly meteorological and agricultural developments on a national and international scale, providing written summaries of weather and climate conditions affecting agriculture, as well as detailed maps and tables of agrometeorological information that is appropriate for the season.

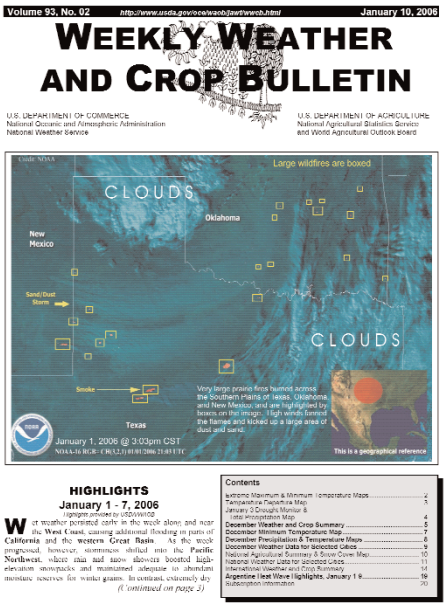


Figure 3-USDA-3. *Weekly Weather and Crop Bulletin* is a joint effort of between the Departments of Agriculture and Commerce.

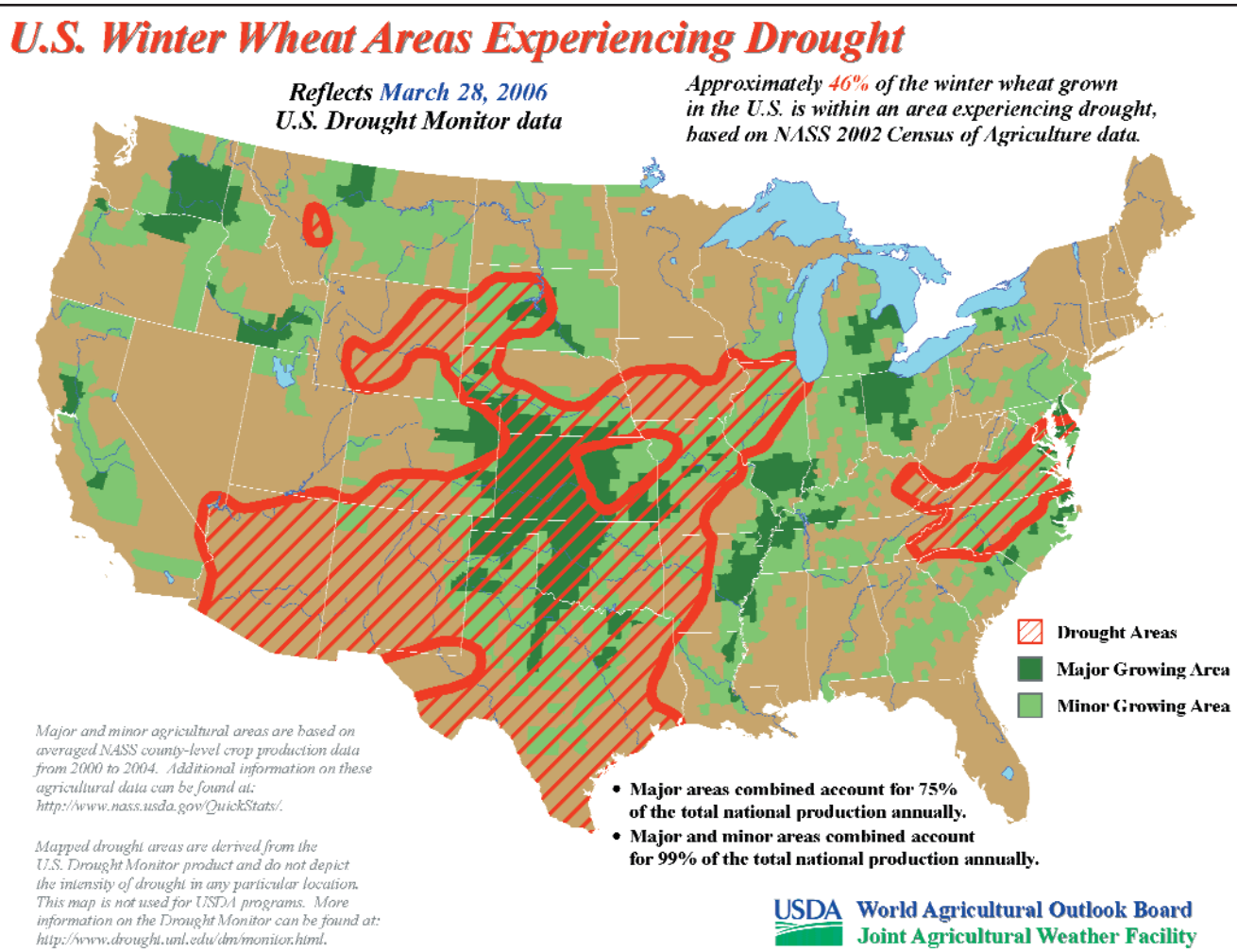


Figure 3-USDA-4. A monthly update of United States winter wheat areas experiencing moderate or more intense drought.

The *WWCB* also provides timely weather and crop information between the monthly *Crop Production* and *World Agricultural Supply and Demand Estimates* reports, issued by USDA/NASS and USDA/OCE/WAOB, respectively. The *WWCB* is available in electronic form from the OCE web site at: *http://www.usda.gov/oce/weather/index.htm*.

Knowledge of historical climate data and agricultural production patterns in agricultural regions around the world is critical in JAWF's assessments of weather's impact on crop yields. In September 1994, OCE/WAOB/JAWF published the *Major World Crop Areas and Climatic Profiles* (Agricultural Handbook No.664). This reference handbook provides the framework for assessing the weather's impact on world crop production by providing information on climate and crop data for key producing regions and countries. Coverage includes major agricultural regions and crops, including coarse grains, winter and spring wheat, rice, major oilseeds, sugar, and cotton. World maps show the normal developmental stage of regional crops by month. An electronic version of the handbook was developed to provide periodic updates to the printed version as additional data become available. The electronic version is available from the OCE web site at: *http://www.usda.gov/oce/weather/pubs/Other/MWCACP/index.htm*.

Drought is one of the most costly natural disasters affecting the U.S. In the summer of 1999, a monitoring tool known as the *Drought Monitor* was developed to help assess drought conditions in the U.S. The *Drought Monitor* is a collaborative effort between Federal and academic partners, including the University of Nebraska-Lincoln National Drought Mitigation Center, OCE/WAOB/JAWF, NOAA/NWS/CPC, and NOAA/NESDIS/National Climatic Data Center. Approximately ten lead authors rotate the responsibility of preparing the *Drought Monitor*. Produced on a weekly basis, the *Drought Monitor* is a synthesis of multiple indices, outlooks, and impacts depicted on a map and in narrative form. The official web site for the *Drought Monitor* can be found at: *http://www.drought.unl.edu/dm/monitor.html*. The *Drought Monitor* is released each Thursday at 8:30 A.M. Eastern Local Time. Because the *Drought Monitor* is prepared in a GIS system, it can be overlaid on agricul-

tural data, to create agricultural weather products that quantify the spatial extent of drought affecting various agricultural commodities (Figure 3-USDA-4). These agricultural weather products, along with the *Drought Monitor*, serve as the main source of information for briefing materials on U.S. drought developments for the Department's Drought Task Force.

The *North American Drought Monitor (NADM)* is a cooperative effort between drought experts in Canada, Mexico, and the U.S. to monitor drought across the continent. The NADM was initiated at a workshop in April 2002, and is part of a larger effort to improve the monitoring of climate extremes on the continent. Issued monthly since March 2003, the NADM is based on the end-of-month *U.S. Drought Monitor* analysis and input from scientists in Canada and Mexico. Major participants in the NADM program include the entities involved with the production of the *U.S. Drought Monitor*, as well as Agriculture and Agrifood Canada, the Meteorological Service of Canada, and the National Meteorological Service of Mexico. The NADM web site is: *http://lwf.ncdc.noaa.gov/oa/climate/monitoring/drought/nadm/nadm-map.html.*

USDA's Chief Meteorologist is currently serving as the president of World Meteorological Organization's (WMO's) Commission for Agricultural Meteorology. In this position, the USDA's Chief Meteorologist leads an effort to enhance the flow of more accurate and timely global agricultural weather information through an ongoing project utilizing Internet technology. The World AgroMeteorological Information Service (WAMIS) is a dedicated web server that provides agrometeorological bulletins and advisories issued by WMO Members to the global agricultural community as well as training modules to aid Members in improving their agrometeorological products. Currently, 25 member services contribute advisories and bulletins to the WAMIS web server. The WAMIS web site is: *http://www.wamis.org*.

The OCE/WAOB/JAWF opened a field office in Stoneville, Mississippi in October 1998. The OCE office in Stoneville, Mississippi is co-located with the Mississippi State Delta Research and Extension Center (DREC) and USDA's Agricultural Research Service (ARS) Mid-South Area Jamie Whitten Delta States Research Center. A primary goal of the field office is to access and link existing agricultural weather data collection networks to assist with the nationwide flow of agricultural weather data and information. This goal is being achieved through ongoing cooperative efforts with other state, public, and government institutions engaged in agricultural weather activities and climate services, including the states of Missouri, Iowa, Alabama, Mississippi, Oklahoma, Illinois, Louisiana, Indiana, NOAA's Regional Climate Centers, USDA's Natural Resources Conservation Service (NRCS), and the U.S. Department of Interior/Bureau of Reclamation/Pacific Northwest Region AgriMet Program. Interactions with these other agencies have helped to ensure the availability of soil temperature data, previously unavailable on a national scale. These soil temperature data are published during the spring and early summer in the *WWCB*. Such data are critical in providing guidance to farmers on when soil temperatures have reached high enough levels to begin planting field crops.

FOREST SERVICE

RESEARCH

Pollutants and emissions from prescribed and wildland fires are decreasing current and future air quality. Forest Service meteorologists are working with biological and social scientists to look at how land use changes (such as transportation patterns), and forest species distributions impact air quality and forest health. Predictions of prescribed and wildland fire and smoke emissions and transport are being used to assess the added impact of fires on air quality and as a planning tool for scheduling prescribed burns to reduce the buildup of hazardous fuels. Research at the Missoula Fire Laboratory, in cooperation with other partners, forms the foundation for many fire weather products as well as smoke management guidelines. Predicting emissions factors from fires and modeling smoke dispersion provides estimates of smoke impacts on human health and relationships between on-site meteorology and smoke dispersion including consequences of smoke to visibility in Clean Air Act Class I Areas.

Air pollution effects remain a serious threat to forest health in some parts of the U.S. Research is focusing on sampling methods and quantifying air quality (nitrogen and ozone) and air quality related values, particularly in remote areas, and on measuring and quantifying impacts of nitrogen deposition on alpine and subalpine terrestrial and aquatic ecosystems. Forest Service's research is also investigating nitrogen deposition in selected forest ecosystems across the U.S., with particular attention to nitrogen deposition effects on nutrient cycling, soil and water chemistry, soil microbiology, plant species composition and abundance, and ecosystem function.

NATIONAL FOREST SYSTEM

The National Forest System weather program works with the USDA Drought Commission. It provides liaison with the Satellite Telemetry Working Group (STWG) on satellite services and with the National Weather Service, DOI, and NWCG on the delivery of fire weather forecasting,

critical for safety and effectiveness of fire fighting and for flash flood warnings. The Forest Service watershed management program provides assistance to the NRCS by conducting snow surveys in 11 western states and Alaska on National Forest System lands to maximize safety and efficiency. Cooperative efforts with NRCS and USGS in the Eastern U.S. include monitoring air and weather stations on National Forest System lands in wilderness areas as well as near large urban centers. This information provides the basis for modification of forest structure through the deposition and melt of snow, flood forecasting, fire season risk, and water management decisions affecting aquatic species, agriculture, hydro-electric, transport & international treaties. Land management and timber harvest impact water yields and storage, can enhance existing water supplies, and can be consistent with other resource uses and values. Snow augmentation or other modification activities carried out by cooperators are consistent with applicable laws, regulations and management guidelines for National Forest System lands.

FIRE AND AVIATION MANAGEMENT

This program uses meteorological data, analysis and prediction tools and expert interpretation skills for decision making regarding wildland fire management including wildfire, wildland fire use and prescribed fire activities. The Forest Service State and Private Forestry, Fire and Aviation Management (F&AM) program operates a network of over 1000 remote automated weather stations (RAWS) in a national network of over 2500 stations. The network provides real-time meteorological information which is key in processing the National Fire Danger Rating System (NFDRS) via the Weather Information Management System (WIMS) used by fire agencies across the country.

The program provides liaison with the Satellite Telemetry Interagency Working Group (STIWG) and its associated Technical Working Group; the National Weather Service (NWS); DOI agencies including the Bureau of Land Management (BLM), Fish and Wildlife Service (FWS), Bureau of Indian Affairs (BIA), and National Park Service (NPS); state fire protection agencies; and the National Wildfire Coordinating Group (NWCG) on the delivery of fire weather data and forecasting, critical for safety and effectiveness in wildland fire management. The RAWS Program assures that the USFS network is in compliance with the National Fire Danger Rating Weather Station Standards; and serves as key contact for any changes to that document on behalf of the Fire Environment Working Team (FENWT). The FS F&AM participates on the NWCG FENWT and other fire weather-related groups to address fire weather standards, translation of fire weather information into models and fire behavior support tools. The FS F&AM program is participating on the OFCM Joint Action Group for the National Wildland Fire Weather Needs Assessment which should be complete in 2007. The RAWS Program provides extensive support to local fire management and national fire management personnel through the hosting and maintenance of the Interagency RAWS web site. The web site address is http://www.fs.fed.us/raws.

The data from this network of stations form the basis for the assessment of fire danger, the pre-positioning of fire fighting resources and the conducting of prescribed fire operations including management of smoke. The costs include maintenance support contracts, maintenance training sessions, contracts for the delivery of this information to agency personnel, fire weather forecasters, and state forestry agencies that use the data in real-time for critical decisions.

The agency fire weather program works with the National Predictive Service Group (NPSG) at the National Interagency Fire Center (NIFC), Boise, ID, in providing technical support and oversight to 10 Geographic Area Coordination Centers and works closely with the Forest Service Research and Development staff in the oversight of the 5 regional Fire Consortia for Advanced Modeling of Meteorology and Smoke. This effort, in cooperation with NOAA and EPA, will provide valuable fire weather predictions, smoke forecasting and air quality information to fire managers and air quality programs nationally.

The F&AM program participates in the Automated Lightning Detection Contract to support quick response to new wildland fire ignitions. The data is delivered in real-time via the BLM's Wildland Fire Management Information System (WFMI). WFMI is accessible via the internet with correct logon and password credentials. State and private forestry agencies are also allowed access to the data through FS sponsorship and funding. The contract with Vaisala is held by the National Weather Service on behalf of several Federal government agencies.

The RAWS program is participating in an interagency Competitive Sourcing Study of the maintenance support required to keep the RAWS network operational and accurate. The study is being led by the BLM. The results will affect all Federal wildland fire agencies and many state forestry agencies and private users. At the conclusion of the study, the newly formed Most Efficient Organization (MEO) will include employees and workload from the USFS, BLM, BIA, NPS, and FWS.

NATURAL RESOURCES CONSERVATION SERVICE)(NRCS)

SNOW SURVEY AND WATER SUPPLY FORECASTING - MONITORING

Snowmelt provides approximately 80 percent of the streamflow in the western U.S.. The NRCS, in partnership with other Federal and state agencies, operates the Snow Survey and Water Supply Forecasting Program (SS&WSF) in 11 western states and Alaska. To accurately forecast seasonal water supplies, the program collects critical snow and climate data from high elevation snow packs in the mountainous western U.S. The data collection system includes 922 manual snow courses and over 703 automated SNOTEL (SNOw pack TELemetry) monitoring stations throughout the western U.S. These data, along with information from 740 stream gauges, 399 major reservoirs, and 3,200 climatological observing stations are merged into a hydroclimatic database that is used to produce real-time watershed analyses and water supply forecasts. Monitoring is done in partnership with Federal, state, and local agencies, power companies, irrigation districts, and the Provincial Government of British Columbia. This information is the basis for water management decisions under international treaties with Canada and Mexico.

The SNOTEL automated data collection system plays an important role by providing near real-time remote hydrometeorological data required to evaluate snowpacks, potential in-stream water supplies and drought risk. The SNOTEL network can provide hourly precipitation, temperature, and snowpack depletion information that significantly improves flood stage forecasts and the monitoring of other life threatening snow-related events. SNOTEL information enables emergency management agencies to effectively mitigate drought and flood damages. An added benefit during the late spring and summer is the availability of hourly climate data, which is used to monitor and assess forest and wildfire potential.

Additionally, the SS&WSF Program supports research to improve monitoring technology, data reliability, data quality, water supply forecasting, and water resource modeling.

WATER SUPPLY FORECASTS

Monthly water supply forecasts are produced each year, January through June, in partnership with the NWS. The purposes of water supply forecasts are to: (1) help irrigators make the most effective use of limited water supplies for agricultural production needs; (2) assist the Federal government in administering international water treaties with Canada and Mexico; (3) assist state governments in managing intrastate streams and interstate water compacts; (4) assist municipalities in planning the early management of anticipated water supplies and drought mitigation; (5) operate reservoirs to satisfy multiple use demands including hydropower generation; (6) mitigate flood damages in levied areas and downstream from reservoirs; and (7) support fish and wildlife management activities associated with species protection legislation.

During a typical forecast season, the NRCS SS&WSF Program issues approximately 11,400 seasonal water supply forecasts for 711 locations in 12 Western states. The water supply forecasts are coordinated and peer reviewed by a number of Federal agencies and cooperators to ensure the highest quality and accuracy. Major cooperators include the Bureau of Reclamation, Corps of Engineers, Bonneville Power Authority, state and local agencies, power utilities, irrigation districts, Tribal Nations, the Provincial Government of British Columbia, the Yukon Territory and Mexico. The primary users of this information include agricultural, municipal, industrial, hydropower, and recreation organizations. Recent Federal legislation related to endangered species protection has placed increased emphasis on timely and accurate forecasts.

The NWCC web site provides snow data, analyses, and forecasts efficiently to approximately 80,000 users. The web site experiences over 2.4 million accesses per month during the snow season.

DROUGHT ASSESSMENT

The SS&WSF Program provides a variety of climate and water supply products that are used to assess western U.S. drought. These include SNOTEL snow pack and precipitation analysis in the mountains, water supply forecasts, and state Surface Water Supply Indexes (SWSI). These products are critical to the weekly production of the interagency *Drought Monitor* web-based report. A cooperative, nationwide network of 108 Soil Climate Analysis Network (SCAN) sites in 39 states monitors soil temperatures and soil moisture to support national drought monitoring, production agriculture, and climate change research.

CLIMATE INFORMATION

NRCS provides climate data and products that directly support agriculture and conservation activities nationwide. Digital maps of monthly and annual precipitation and temperature for the U.S. are available from the NWCC web site (Figure 3-USDA-5). To meet the needs for real-time climate in formation and analysis, the SS&WSF program and the NOAA climate program are sponsoring the Applied Climate Information System (ACIS). ACIS is an internet-based climate data delivery system that provides the NRCS field offices, USDA, and partners with internet access to thousands of climate data sets collected by scores of Federal, state, and county networks. To support agricultural modeling efforts, the NWCC is also providing serially complete (i.e., no missing data values) temperature and precipitation data for approximately 11,000 climate stations nationwide. NRCS long range planning is supported by the Generation of weather Elements for Multiple (GEM)

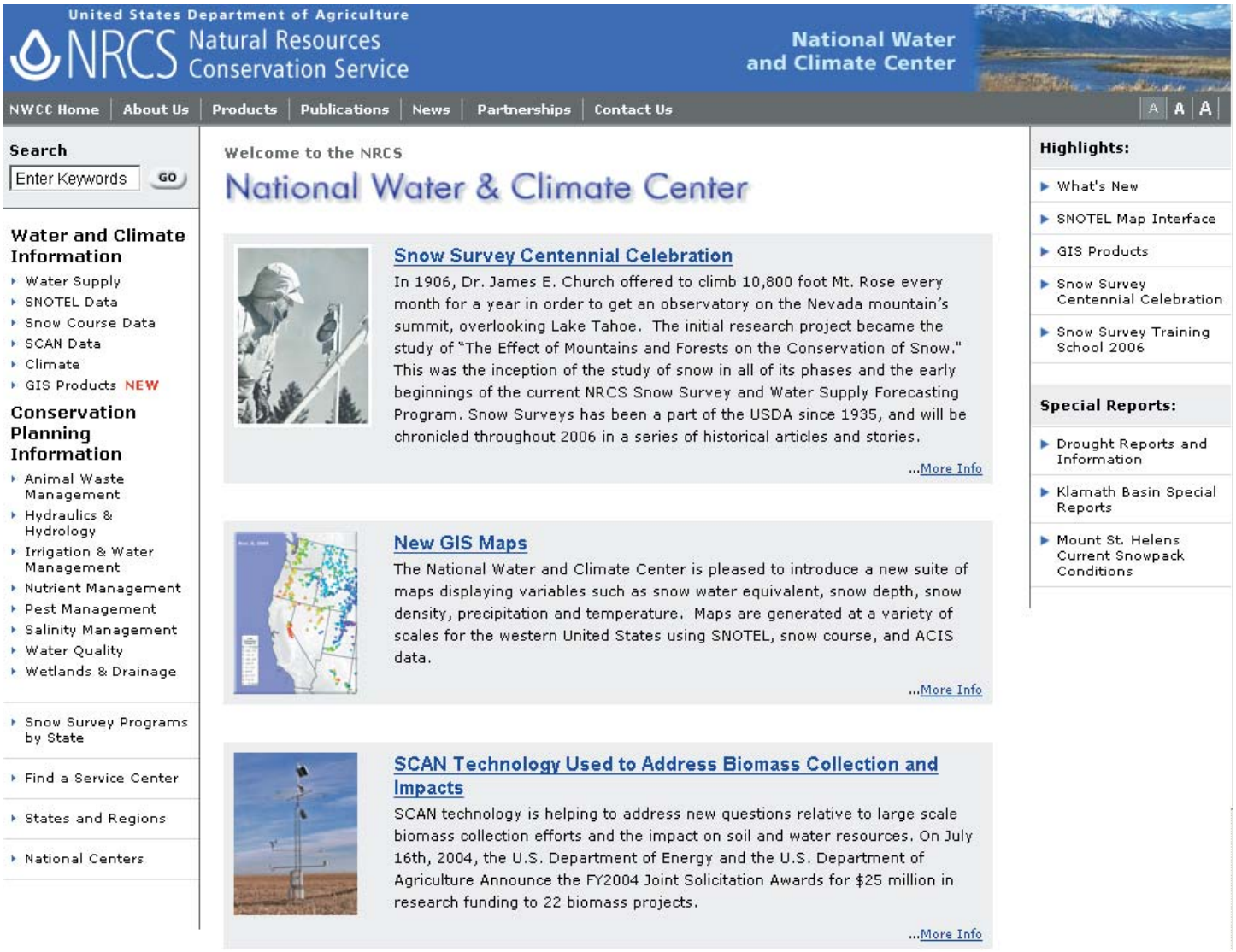


Figure 3-USDA-5. Natural Resources Conservation Service Web Site, where digital maps of monthly and annual precipitation and temperature are available.

applications model, which has been used to generate future climate data sets for more than 250 locations nationwide. GEM is being integrated with several NRCS environmental models. Monthly precipitation averages and growing season length information required for wetlands analysis are also available from the NWCC web site at over 6,000 locations in the United States, plus Guam and Puerto Rico. Finally, wind roses for 237 NWS stations in the United States, plus offices in Guam and Puerto Rico are now available from the NWCC web site. A wind rose gives a very succinct but information-laden view of how wind speed and direction are typically distributed at a particular location. Wind roses are useful planning tools for agricultural and natural resource planning.

AGRICULTURAL RESEARCH SERVICE

Research in this area focuses on how annual variation in weather impacts crop and animal production, soil erosion, irrigation scheduling, water availability, fate and transport of pollutants, and the environmental and economic sustainability of agricultural enterprises. Scientists are developing algorithms and decision support systems for the development of a stochastic storm-generator model and methodology to use contemporary weather radar systems to determine rainfall amounts and the spatial distribution and variability in precipitation associated with individual storms. Scientists are working on incorporating weather information and climate forecasts to improve irrigation scheduling and water use efficiency across the western U.S. Research in conjunction with NRCS and NASA is being conducted to map snow packs and predict water yield in the western U.S. The ARS watershed network is partnering with the NRCS in measuring and reporting soil temperature and moisture (Soil Climate Analysis Network (SCAN)) in addition to standard weather variables to help in

understanding and forecasting the impact of drought on crop and forage production across the nation. Additional research is being conducted to integrate seasonal forecasts, other information on extended climate departures from normal and extreme events, corresponding agricultural responses, and associated uncertainties into planning and management decision aids readily useable by producers. The research is conducted in collaboration with the NOAA forecast developers.

COOPERATIVE STATE RESEARCH, EDUCATION AND EXTENSION SERVICE

Funding from the Cooperative State Research, Education and Extension Service (CSREES) supports research projects that collect and process long-term weather and climatic data and provide immediate and future use as a base of information for the projection and prediction of climatic trends related to environmental impacts of human activities, soils, crops and domestic animals on agroecosystems, forest, and rangelands. Broader areas of study involve climatic dynamics, carbon and water cycling, and their role in global change. The impact of changes in UV and ozone level studies also fit into this broad global category.

Historical climatic changes are related to trends visible from present data gathering studies, enabling prediction of future crop production and irrigation needs. CSREES funding supports studies on the impact of climate and weather on food and fiber production. These studies relate to forest plant growth, rangeland productivity, cropping system selection and livestock production practices.

Man's impact on climate systems is also well represented in studies of both micro- and macro-climatic change. These involve studies dealing with the climatic impact of changes in air quality, water quality and point/non-point pollution related to agricultural practices and forest and urban development. Studies on climatic impact on nutrient cycling and carbon sequestration are supported with CSREES funds. Research is also being supported that quantifies the impact of climate change on the incidence and severity of plant and animal diseases and pests, invasive species, and biodiversity.

The National Research Initiative (NRI) has funded a wide variety of weather and climate research. Topics have varied from a number of fundamental plant drought tolerance studies to using meteorological data to forecast market performance. Much of the support in this area is also focused on climate change. The NRI has also funded research on how land changes have influenced climate and vice versa.

DEPARTMENT OF ENERGY AND NATIONAL NUCLEAR SECURITY ADMINISTRATION (NNSA) OPERATIONAL AND RESEARCH WEATHER PROGRAMS

For almost 60 years, the Department of Energy (DOE) and its predecessors, the Atomic Energy Commission (AEC) and the Energy Research and Development Administration (ERDA), have established and supported meteorological operations and atmospheric research at the DOE field facilities. The need for meteorological services began in 1944 with the development, fabrication, and testing of atomic weapons and their accompanying national security and safety issues. Meteorological program requirements were subsequently augmented, starting in the late-1960's, by the passage of environmental protection legislation under the Clean Air Act, which is enforced by the Environmental Protection Agency (EPA) under 40 CFR enabling regulations, and reinforced by several DOE Orders that specify requirements for meteorological services to protect public health and safety and the environment. Consequently, a meteorological monitoring program has become an even more essential component of each DOE site. Moreover, the acquisition of quality-assured meteorological data and the provision of weather forecasting services is an important element of a DOE Integrated Safety Management System (ISMS). It significantly contributes to the implementation of site-wide personnel safety programs along with site evaluations. These evaluations include, but are not limited to the following: protection of facility workers and the public; development of Authorization Basis (AB) safety documentation; diagnostic and prognostic consequence assessment elements of an emergency management system; preparation of permits to support environmental compliance activities; and, impact analyses of construction and operation of projects and missions requiring National Environmental Protection Act (NEPA) determinations.

OVERVIEW OF DOE AND NNSA OPERATIONAL METEOROLOGICAL PROGRAMS AND SUPPORTING RESEARCH

Recognition of the need for site-specific meteorological services began in 1944, with the development, fabrication, and testing of atomic weapons and their accompanying national security and safety issues. In response to this need, the Department of Energy (DOE) and its predecessors, the Atomic Energy Commission (AEC) and the Energy Research and Development Administration (ERDA), and the current National Nuclear Security Administration (NNSA), have established and supported operational meteorological programs and atmospheric research projects at many DOE and NNSA field offices.

Operational meteorological program requirements were subsequently augmented, starting in the late-1960's, by the passage of environmental protection legislation under the Clean Air Act (CAA), enforced by the Environmental Protection Agency (EPA) under 40 Code of Federal Regulations (CFR) enabling regulations, and reinforced by several DOE directives (e.g., DOE O 5400.1) that specify requirements for meteorological services to protect facility worker health and safety, public health and safety, and the environment. Since that time, the CAA has been amended on three occasions, each time including broader requirements, inclusive of stratospheric ozone protection regulations. Consequently, an effectively managed meteorological monitoring program has become an even more essential component of operations at each DOE and NNSA site.

Moreover, the acquisition of quality assured meteorological data, the provision of weather forecasting services, and the development of site-specific climatology from these meteorological programs is an important element of a DOE Integrated Safety Management System (ISMS) that significantly contributes to the implementation of site-wide personnel safety programs and supports multiple evaluations. These evaluations include, but are not limited to the following:

- Protection of facility workers and the public;
- Development of nuclear and chemical safety documentation (e.g., Safety Analysis Reports);
- Diagnostic and prognostic consequence assessment elements of emergency management programs;
- Preparation of air and surface water permits to support environmental compliance activities; and,
- Impact analyses for construction, operation and decommissioning of projects, and missions requiring National Environmental Protection Act (NEPA) determinations.

DOE and NNSA continue to address their fundamental mission areas of national security, science and technology, energy security, and environmental clean up of cold war production sites. Meteorology and atmospheric science contributes to many of these

mission elements. Consequently, atmospheric science research programs and weather forecasting operations have been an integral part of DOE, NNSA and its predecessor agencies since World War II. Therefore it is vital to understand the nature of the atmospheric domain and its relationship to terrestrial, ocean, and other environmental domains. Understanding these relationships feeds into the reduction of uncertainties regarding climate change research.

DOE and NNSA administer programmatic activities throughout their various offices, such as the Office of Science (SC), Environmental Safety and Health (ES&H), the National Nuclear Safety Administration (NNSA), and Environmental Management (EM), in which each has some linkages to meteorology and atmospheric science. Some of these program offices are responsible for the management of scientific research programs, such as the National Atmospheric Release Advisory Capability (NARAC), Global Climate Change Research (GCCR), and various environmental cleanup activities at former DOE production sites. Additional activities at DOE and NNSA sites include support to daily operations and national defense programs; all of which require a fundamentally sound well-managed meteorological monitoring program.

Meteorological services at DOE and NNSA facilities range from the conduct of cutting-edge basic research to providing daily support to operational programs and construction projects. Some examples of research and development are investigations of potential global climatic change, radiation transfer mechanisms and cloud studies, lightning and thunderstorm studies, atmospheric chemistry, atmospheric tracer studies, and studies of atmospheric planetary boundary layer processes. Operational support programs include daily-customized weather forecasting services, support to national defense projects and homeland security, on-site meteorological monitoring programs, climatological services, occupational health and safety program support, and emergency management program support.

Some DOE and NNSA sites maintain a 24-hour weather watch for severe weather conditions that have the potential to impact site operations, damage property, or threaten lives. DOE-wide and NNSA-wide lightning safety initiatives, which are becoming integral elements of an Integrated Safety Management System (ISMS), are supported by DOE and NNSA operational meteorological programs (e.g., Nevada Test Site (NTS), Hanford, Savannah River Site (SRS), Idaho National Engineering and Environmental Laboratory (INEEL)).

A number of DOE and NNSA field offices and their associated sites and facilities cover large areas (e.g., INEEL, Oak Ridge Reservation (ORR), NTS, Hanford, and SRS). In addition, several DOE and NNSA sites are situated in areas of complex topography and heterogeneous surface characteristics (e.g., land-water interface), creating mesoscale conditions that locally influence on-site weather and more importantly, airflow trajectories associated with atmospheric transport and dispersion. This is why DOE originated a research program addressing Atmospheric Studies in Complex Terrain (ASCOT) during the eighties and early nineties to address emergency response issues in complex terrain environments at the various DOE sites.

For these reasons, and to ensure the protection of public health and safety and the environment, on-site meteorological monitoring programs have been, remain, and will always be an essential part of DOE and NNSA atmospheric science programs. Moreover, partnerships have been forged with other Federal agencies (i.e., Department of Commerce (DOC) via its National Oceanic and Atmospheric Administration (NOAA)) to leverage research resources addressing complementary mission areas.

Some DOE and NNSA sites enhance the spatial resolution of the National Weather Service (NWS) observing network by taking standard surface and upper-air observations. Many of these sites are in remote areas where NWS and community weather observations would otherwise be limited. Weather observations taken at a few DOE and NNSA field sites are entered into the database via the NWS meteorological data distribution and display system. This distribution and display system interconnects field offices and serves as the distribution system for NWS meteorological products that are centrally produced by the National Centers for Environmental Prediction (NCEP). Some DOE and NNSA sites (e.g., NOAA Air Resources Laboratory (ARL)/Special Operations and Research Division (SORD), Las Vegas, NV) employ the NOAA Advanced Weather Information Processing System (AWIPS), as well as vertical profilers and meteorological monitoring networks.

An accidental release of radioactive, chemical, or biological toxic material into the atmosphere can have potentially serious health effects, as well as environmental consequences. Meteorological transport and dispersion processes play a key role in determining the fate of radioactive, chemical, or biological agents released into the atmosphere; including those resulting from malevolent acts. Consequently, a central theme within the DOE and NNSA community has been to protect public health, safety, and the environment on and around DOE and NNSA facilities by accurately measuring and characterizing the important local atmospheric processes necessary to characterize atmospheric transport and dispersion.

In recognition of the aforementioned

needs and requirements, DOE and NNSA have established and continue to support on-site meteorological monitoring programs since the commissioning of an operational meteorological program in 1944 at Hanford. Each meteorological program contributes to the support of emergency management programs and focuses on the protection of the environment and the safety and health of the on-site work force and the public. In addition, research on the modeling of the transport, dispersion, deposition, and resuspension of radioactive, chemical, and biological agent materials is undertaken to refine the transport and dispersion models used in these endeavors. New remote sensing techniques are being developed, such as the "Best" Aircraft Turbulence probe at the ARL Field Research Division (FRD), in Idaho Falls, ID. On-site weather forecasting services, each tailored specifically for the special operational and emergency management requirements at each DOE and NNSA site, provide necessary support to the safety and health programs designed to protect site personnel, the public, and the environment.

Over the years, operational and research meteorological programs have grown to address and support many environmental, safety, and health issues. Due to the complexity of activities, it was recognized that efforts should be made to coordinate meteorological operations and research among the field offices to enhance cost effectiveness and productivity. To address these considerations, the DOE Meteorological Coordinating Council (DMCC) was formed in 1994, and has been providing support to DOE and NNSA meteorological programs for 10 years. The following narrative highlights meteorological activities at 15 separate DOE and NNSA sites. The activities are subdivided into operational and research components. The DMCC narrative is the last entry signifying the importance of this program in alleviating meteorological and safety coordination across the DOE sites.

ARGONNE NATIONAL LABORATORY (ANL)

Operational

Argonne National Laboratory (ANL) is one of DOE's largest research centers. It is also the nation's first national laboratory, chartered in 1946. ANL is managed and operated by the University of Chicago (UC) for the DOE Chicago Operations Office. Argonne occupies two sites, designated as ANL-East in Illinois and ANL-West in Idaho. The Illinois site is surrounded by forest preserve on 1,500 wooded acres about 25 miles southwest of Chicago's Loop. The site also houses the DOE Chicago Operations Office. Argonne-West occupies about 900 acres about 50 miles west of Idaho Falls in the Snake River Valley. It is the home of most of the ANL major nuclear reactor research facilities.

There are three divisions, Environmental Research (ER), Decision and Information Sciences (DIS) and Environmental Assessment (EAD) at ANL with meteorological research or operational program support. Two cross-divisional groups are involved in these programs at ANL: the Atmospheric Research Section (ARS) and the Atmospheric Emergency Preparedness (AEP) Group. The ARS is composed of scientist with research activities in both basic and applied science; particular technical strengths are in the areas of air-surface exchange, remote sensing, atmospheric chemistry, and numerical modeling. About half of the ARS support is currently devoted to activities associated with the DOE Atmospheric Radiation Measurement (ARM) Program. The AEP is composed of scientists and engineers in two divisions involved in programs with a greater emphasis on applied science. Particular technical strengths include air pollution meteorology, emergency preparedness and response, and stochastic systems simulations. More than half of the AEP support is associated with the DOE Protect Critical Infrastructure Program involving chemical and biological agents.

ARS operates and maintains a 60-meter meteorological tower and supplies meteorological data for emergency response, facility operations, and regulatory compliance for ANL operations. Wind and temperature measurements are taken at the 10-meter and 60-meter levels. Real-time and historical data are available via the Web (http://gonzalo.er.anl.gov/ANL-MET).

Research

As part of a larger program for the protection of subway systems from terrorist attacks using chemical agents, AEP Group is installing sonic anemometers as well as temperature and pressure sensors in the subway tunnels of a large urban subway system. These instruments will assist in the understanding of flows in the tunnels, which are driven by a combination of:

- The "piston" action of train motion; and,
- Buoyancy effects and above-ground forcing.

Measurements from these instruments will be correlated with the above ground measurements to develop and validate predictive and emergency response models for flow and dispersion in subway systems.

The AEP group research also focuses on the analysis of routinely measured meteorological data to provide atmospheric boundary layer turbulence information for atmospheric dispersion calculations. Under the Department of the Army Chemical Stockpile Emergency Preparedness Program (CSEPP), ANL provides support to improve the collection efficiency and

quality of meteorological data measured at the Army's Demilitarization towers. The data are used the emergency operation centers in support of emergency response exercises and for use in real-time in the event an actual accident. The goal of the CSEPP support is to improve the accuracy and robustness of the data obtained from the meteorological monitoring stations and to develop unified quality control and analyses procedures of the data collected by the towers.

Key support is also provided to Department of Transportation (DOT) in applying an ANL-developed 5-year meteorological database for over 100 locations in the U.S. to conduct statistical analyses of hazardous materials incidents on a national basis. Recent work for DOT has centered on development of the Table of Initial Isolation and Protective Action Distances for the *2000 Emergency Response Guidebook*. Protective Action Distances are given in the Table for over 200 toxic-by-inhalation chemicals and generic compounds for both daytime and nighttime accidents, and represent the safe distance for 90 percent of hazardous materials transportation accidents considering variability in meteorology and spill size. Recent work for DOT has also involved conducting national risk assessments for transportation of certain high volume toxic chemicals like chlorine, ammonia, hydrogen fluoride and sulfur dioxide.

The Atmospheric Boundary Layer Experiments (ABLE) is one of several DOE supported research programs conducted by the ARS (Figure 3-DOE-1). ABLE is located on the lower Walnut Watershed, mostly in Butler County east of the city of Wichita, KS. This location is within the existing boundaries of the DOE ARM Southern Great Plains (SGP) Clouds and Radiation Test-bed (CART) site. The establishment of this facility offers a virtual atmospheric observatory and provides essential research tools for addressing a myriad of unresolved fundamental questions in atmospheric research. The ABLE provides a continuous view of processes in the lower atmosphere over a limited domain within the SGP CART site.

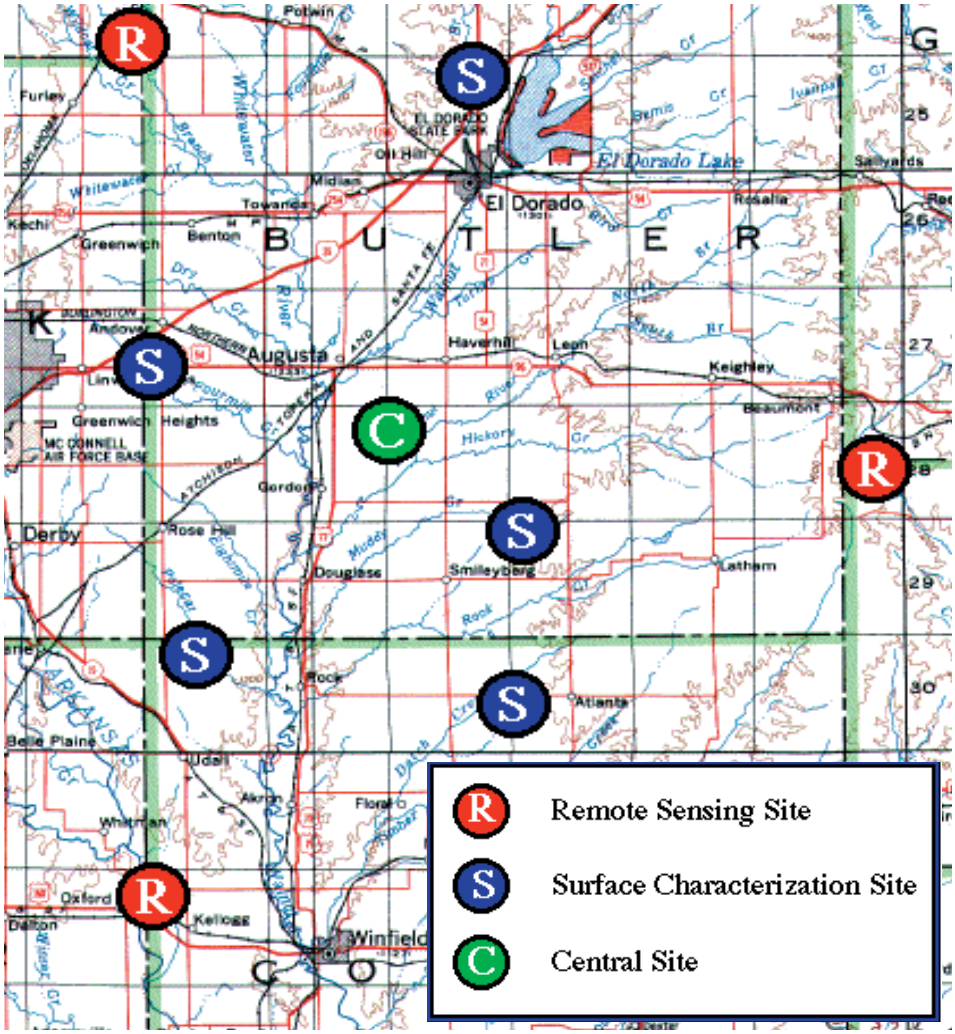


Figure 3-DOE-1. DOE Atmospheric Boundary Layer Experiment (ABLE) site locations in the Midwest.

The initial focus of ABLE is measurement of the planetary boundary layer (PBL) where almost all interactions between the atmosphere and humans take place. Many scientific issues may be addressed by use of such a facility, including:

- Natural disaster reduction and public safety;
- Safe and efficient aviation and other transportation;
- Agriculture;
- Water resource management;
- Effective energy production, use and environmental protection;
- Space flight operations;
- Defense; and,
- Related areas of Earth Science.

Instrumentation at the ABLE site includes winds, temperatures, moisture, surface net radiation and soil moisture as the minimum set of atmospheric observations.

The initial set of equipment, which is available at ABLE includes:

- Three 915 MHz RWP-RASS (wind speed and direction, virtual temperature profiles);
- Three minisodars (wind and turbulence profiles between heights of 10 m and 200 m);
- One lidar ceilometer (cloud base height);
- One balloon-borne sounding sys-

tem (wind, temperature, moisture profiles);

• Five surface flux stations (surface sensible and latent heat, ground heat storage);

• Five soil moisture sampling stations (soil moisture, soil temperature);

• One satellite data receiver-processor;

• One data hub/central location for data collection; and,

• One (extra) instrument pad for visiting scientist instrument accommodation.

BROOKHAVEN NATIONAL LABORATORY (BNL)

Operational

The BNL, under the responsibility of the Brookhaven Area Office, has been active in both operational meteorology and atmospheric sciences for the past 50 years. BNL is now managed by Brookhaven Science Associates, which is a joint venture by Battelle Memorial Institute Incorporated, The Research Foundation of the State University of New York at Stony Brook, and six other core university partners. Meteorological operations and research cover a wide range of programs encompassing interpretive and theoretical studies. BNL is located near the geographical center of Long Island, New York. Long Island is glacial in origin and, as a result, has sandy soil, mostly gentle undulating contours, and a single water aquifer for the entire island. Elevations vary between 20 meters and 35 meters. The BNL site is rectangular and approximately 5,200 acres in area. Winds are predominantly southwesterly, and plume dispersion studies show that it is essential to monitor winds well beyond laboratory borders. The New York City NWS Weather Forecast Office is located at BNL. This office has an umbrella of coverage that includes an estimated population of one million. Nearby, in Bohemia, is the NWS Eastern Regional Headquarters that administers a 12-state region.

The mesoscale meteorological measurements necessary for emergency response are the responsibility of the Meteorological Services Group, a support group under the Department of Applied Science, Environmental Biology and Instrumentation Division (EBID).

The Meteorological Services Group maintains two meteorological towers, 10-meter and 88-meter, and an instrument shelter. By integrating redundant pairs of standard, approved meteorological sensors throughout the system, an overall data availability of better than 99 percent is achieved. The real-time data are merged into the laboratory emergency response network. A database of 50 years (in digital format since 1960), one of the longest continuous meteorological time series in the U.S., is archived and is available. A real-time monitoring network with worldwide web access covers the eastern end of Long Island. Coastal weather stations at Smith Point and Orient Point transmit data each minute. Pollution-monitoring data buoys are added during field programs.

The Meteorological Services Group provides a locally tuned forecast twice daily during normal working hours. Weather forecasts and data are available by telephone or the Internet (www.weather.bnl.gov). During severe weather events updates are given every three hours and, in the case of a hazardous material or radiological release, a member of the Meteorological Services Group will assist the emergency coordinator with regular forecasts and information on local wind fields and gustiness.

Research

Areas of meteorological research at BNL include:

• Instrumentation development for field studies of atmospheric constituents, air-sea interaction, and laboratory experiments;

• Gaseous tracer studies of atmospheric transport and dispersion;

• Aerosol formation and behavior;

• Atmospheric pollution studies

• Modeling of atmospheric chemical reactions;

• Acid rain studies both in the field and in the laboratory;

• Theoretical and observational studies of radiation transfer and fluxes; and,

• Analysis of data and development of parameterizations relevant to global climate change.

The ARM Program provides the stimulus for a wide range of climate-related studies. The ARM ocean monitoring program is developing instrumentation and a broad ship- and buoy-based observational network in the tropical western Pacific Ocean. The Atmospheric Chemistry Program (ACP) supports the Atmospheric Chemistry Division's (ACD) concern with aerosol sources, transport, and fate in the global atmosphere and the overall, and the little understood, impact of aerosols on global climate dynamics. The ARM External Data Center is the center for collection, archival, and dissemination of all climate-related data sets for the ARM program.

An exciting new effort in radar meteorology focuses on algorithms for cloud detection and cloud mapping using both the WSR-88D radar network and research radar. BNL is a site in the National Aeronautical and Space Administration (NASA) Solar Irradiance Network and continuous short wave absorption measurements are

made here. In a related NASA study, oceanic aerosol optical depths are measured and used to validate absorption algorithms in the SeaWiFS ocean color program.

The Optical Remote Sensing (ORS) group within the Department of Advanced Technology (DAT) is presently modifying one of its Raman lidar systems for vertical profiling of carbon dioxide. The Raman lidar instrument is a self-calibrating sensor that means that data from a variety of locations in the world can be compared. With the incorporation of a large (1.25 m) antenna and advanced filters and detectors, a vertical profile of CO2 concentration with a precision of 1 part per million (ppm) (Note: atmospheric mean = 370 ppm) and maximum height of two to three km can be produced routinely. These profiles will support model development and validation. Importantly, comparison of CO2 concentrations collected throughout the world and over time will prove invaluable in confirming adherence to the Kyoto protocols.

HANFORD SITE

Operational

Beginning in 1944, meteorological services have been provided to the Hanford Site. The Hanford Site is an area of 560 square miles within the semi-arid and sparsely vegetated Columbia River basin in southeastern Washington near Richland, Washington. Since 1965, the Pacific Northwest National Laboratory (PNNL) operated for the Department of Energy (DOE) by the Battelle Memorial Institute, has managed the Hanford Site meteorological program. Not only has operational support been provided, but also supporting research into atmospheric processes has been a key part of the PNNL support to DOE. Within PNNL, the Environmental Technology Directorate provides day-to-day operational meteorological and emergency response support to the Hanford site.

Through funding from DOE, the PNNL Meteorological and Climatological Services Project (MCSP) provides meteorological monitoring and operational support to the Hanford Site. The monitoring system consists of an array of 26 10-meter towers, three 60-meter towers and one 125-meter tower instrumented with temperature and wind direction and wind speed sensors (Figure 3-DOE-2). Atmospheric pressure and precipitation data are also collected by this monitoring system. Meteorological data from this network is transmitted via UHF radio to a computer, which decodes the data and plots graphics products for immediate display and use by Hanford Meteorological Station personnel.

Meteorological services include emergency response functions, weather forecasting for on-site operations and special projects, and climatology support. MCSP support to the Hanford site includes: extensive data acquisition via a site-wide meteorological monitoring network; weather forecasting services 24-hours/day during Monday through Friday; weather forecasting services eight-hours/day on weekends and holidays; hourly surface observations, and six-hourly synoptic observations; monthly and annual climatology data summaries; and, meteorological input to annual environmental reports.

PNNL atmospheric sciences staff operate meteorological, atmospheric transport and dispersion and dose assessment, and information display workstations at the Hanford Site's Emergency Operations Center (EOC). Atmospheric sciences staff are involved in facility planning, exercise development, and training activities for Hanford's emergency preparedness program. Assistance is also provided to state and local emergency operations facilities. PNNL staff members have developed MetView software to graphically display Hanford Site and regional meteorological data to support a variety of emergency preparedness and research applications. Staff members have also developed the Air Pollutant Graphical Environmental Monitoring System (APGEMS)-family of software products to improve the ability to rapidly and accurately estimate the atmospheric transport and dispersion and human health and environ-

mental consequences of accidental or unexpected releases on or near the Hanford Site. The flexible user interface and graphical output capabilities of APGEMS allow it to efficiently support a range of users including first responders, experienced hazard assessors, and decision makers.

Research

The Fundamental Sciences Directorate conducts research into meteorological, climatological, and atmospheric chemical processes in support of other major DOE programs such as the Atmospheric Radiation Measurements (ARM) program and the Atmospheric Science Program (ASP).

Figure 3-DOE-2. Meteorological towers record temperature and wind direction and speed at various levels.

PNNL plays both management and developmental roles in the ARM program which is focused on the development of cloud and radiation databases and data products that are critical to improved understanding of global and regional climate change and the improvement of climate research and prediction models. In addition to of its roles in ARM, PNNL also conducts research into the processes affecting radiation transfer through the atmosphere and the effects of greenhouse gases, aerosols, and clouds on regional and global climate. The PNNL Atmospheric Remote Sensing Laboratory is a portable system for studying the vertical structure of atmospheric constituents, particularly clouds, which govern radiation transfer through the atmosphere. Capabilities of the Environmental and Molecular Sciences Laboratory (EMSL) are used to conduct molecular level research into aerosol formulation and aging. Carbon dioxide emissions research is aimed at providing a scientific basis for forecasting future emissions of carbon dioxide and other gases of radiative importance.

In support of the ASP, PNNL uses ground-based and airborne measurements systems, numerical and conceptual modeling, and data analysis to conduct research into the vertical transport and mixing processes that govern the distribution in the lower troposphere of trace gases and aerosols released during energy production or use and on chemical processes that govern the transformation and fate of gaseous and particulate pollutants. PNNL manages the DOE Research Aircraft Facility, a Gulfstream 159 twin turboprop aircraft that supports research in atmospheric chemistry, radiation transfer, and aerosol characteristics for DOE.

A hierarchy of atmospheric dispersion models is being developed within DOE's Chemical Biological National Security Program (CBNP) covering transport distances ranging from around individual buildings, through the urban area and beyond the urban area into the surrounding region. These models will allow individuals in intelligence, law enforcement and emergency management to adequately plan against, train for and respond to potential terrorist attacks. PNNL scientists, in collaboration with other government and private scientists, are conducting atmospheric tracer and meteorological field studies for evaluating the models being developed within CBNP. The field studies will provide valuable information to all investigating urban dispersion, urban air quality and atmospheric transport and dispersion in general.

IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY (INEEL)

Operational

INEEL is managed by the Idaho Operations Office and is on 890 square miles of rolling, arid terrain in southeastern Idaho at the foot of the Lost River and Lemhi mountain ranges. The primary mission of the INEEL for years has been nuclear reactor research with a focus on cleanup and environmental restoration. Meteorological services and supporting research are provided to INEEL via NOAA ARL Field Research Division (FRD). The Division, under administration from various agencies, has provided support to INEEL for over 50 years. Its current mission to DOE/ID is to support emergency response and operations with real-time meteorological data, climatology data, weather predictions, dispersion calculations, and consultation. ARL FRD maintains other capabilities that are not funded directly by DOE. ARL FRD designs, arranges, and conducts field studies as needed to evaluate the performance of transport and dispersion models over local, regional, and continental scales, and to obtain high quality databases for model improvement. An airborne geosciences program is also maintained to measure fluxes of carbon dioxide, water vapor, and other atmospheric constituents that affect climate. These

interactions provide ARL FRD staff with additional insights that aid in the understanding of local meteorological phenomena.

ARL FRD operates a large meteorological monitoring network to characterize the meteorology and climatology of the INEEL site. The network consists of 33 meteorological towers that are deployed both on-site and off-site. The overall meteorological measurement program is designed to provide representative data for the INEEL to meet specific operational and potential emergency response situations. The network covers an area of approximately 15,000 square miles. Many of the towers are 15-meters tall and provide wind speed and direction at 15-meters and air temperature at 2-meters and 15-meters. Instrumentation on 15 of the 15-meter towers also measure relative humidity at 2-meters, precipitation, and global solar radiation. Barometric pressure is provided on 11 of the towers. The other three towers range from 46-meters to 76-meters in height and are instrumented at multiple levels. The sensors at all stations are scanned every second and averaged or totaled over five minutes.

The data are subsequently retrieved into the data display and archive system at the ARL/FRD office through a radio repeater located at an elevation of 8,930 ft MSL. Continuous wind and temperature profiles are obtained from a 915 MHz radar wind profiler and RASS. A Doppler SODAR supplements the wind profile at lower levels with higher resolution data. Meteorological data are quality-controlled through automated and manual processes.

INEEL meteorological monitoring and emergency response efforts are enhanced with the use of an ARL FRD meteorological data display and visualization program known as INEELViz. This program has been widely deployed at 50 sites on and around the INEEL for access by Federal, state, and Indian tribes via the Internet.

Within INEELViz, meteorological data are displayed in real-time and overlaid on maps of the local area that include political and terrain features. In addition, the local MDIFF puff dispersion model can be accessed through the INEELViz front-end and the model output can be displayed as trajectories or concentration isopleths on the INEELViz display screen. The incorporation of RSAC dose conversions permits the user to also view real-time dose estimates from the model output. These features have become very useful enhancements to the INEEL emergency response capability.

Research

Partnerships forged with DOE/ID, the State of Idaho INEEL Oversight Program, and the Shoshone-Bannock Indian Tribes have resulted in additional methods of meteorological data dissemination. Meteorological and background nuclear radiation data from four public access sites on and surrounding the INEEL are displayed at nearby kiosks in real-time. Additional information on nuclear radiation and meteorological tutorials are presented at the kiosks. The data are also available on the Internet at http://oversite.inel.gov. ARL FRD maintains its own web site at www.noaa.inel.gov.

LAWRENCE LIVERMORE NATIONAL LABORATORY (LLNL)

Operational

LLNL is located in a valley in California's Coast Range Mountains about 25 miles east of Oakland. LLNL covers approximately 2 square miles and is operated by the University of California for the DOE Oakland Operations Office. Two groups are involved in the atmospheric sciences at LLNL:

1. Environmental Protection Department (EPD); and,
2. Atmospheric Sciences Division (ASD).

EPD operates a 40m tower and supplies meteorological data for facility operations, regulatory compliance, and emergency response. Real-time and historical data are available at http://www-metdat.llnl.gov/.

The National Atmospheric Release Advisory Center (NARAC) is a centralized emergency response resource supporting Federal agencies (http://narac.llnl.gov/). The mission of NARAC is to deliver realistic real-time graphical dose and exposure assessments to emergency decision-makers to assist in the protection of populations at risk for releases of radiological and other hazardous material to the atmosphere (Figure 3-DOE-3). NARAC has developed specific tools to assist elements of the DOE Consequence Management assets, including the Nuclear Emergency Search Team (NEST), Accident Response Group (ARG), Federal Radiological Monitoring and Assessment Center (FRMAC) (http://www.nv.doe.gov/programs/frmac/default.htm), and the Radiological Assistance Program (RAP). Under DOE direction, NARAC supports National Special Security Events, such as the winter 2002 Olympics. NARAC also supports DOE sites and Emergency Operations Centers around the U.S. (http://www.nnsa.doe.gov/).

NARAC's central emergency response system consists of automated continuous worldwide meteorological data acquisition, detailed worldwide terrain and geographic mapping databases, a suite of atmospheric dispersion models and source models to assess explosions, fires, spills, or other types of radiological, chemical, biolog-

ical releases. The system includes a high-resolution, terrain-following, variable-gridded diagnostic meteorological model (ADAPT) and a prognostic model with parameterizations for urban settings (COAMPS) coupled with a generalized Lagrangian particle dispersion model (LODI).

A staff of NARAC emergency response model experts provides a 24-hour response service. To minimize response time, NARAC has developed and supplied over 40 Federal facilities around the U.S. with software that performs meteorological data acquisition, local-scale stand-alone modeling, and reaches back to LLNL for detailed simulations. NARAC mapped products are delivered in 5-10 minutes for a computer-linked site and up to 60 minutes for a non-computer-linked site. Supported sites and organizations can use the client-server-based NARAC iClient tool (for heavy modelers) or NARAC Web (for light modelers) tools to run models and seamlessly distribute products to multiple organizations over the world wide web.

The Regional Modeling and Dispersion Group is investigates regional scale processes affecting dispersion. This group works with the Urban Group to with the goal of developing a seamless set of validated diagnostic and prognostic tools from the building to urban to regional scales. In collaboration with LANL, LLNL developed a prototype prediction capability to assist in multi-agency smoke and fire management of wildfires.

Research

Scientists in the Atmospheric Science Division (ASD) (http://asd.llnl.gov/) at LLNL perform pioneering research on global climate and chemistry and predict the local, urban, regional, and global transport and fate of hazardous and toxic pollutants. Research is focused on major national energy and security policy issues and is based primarily on development and use of advanced computational simulations of the atmosphere, oceans, and biosphere.

ASD conducts research in four areas:

- Atmospheric hazards and consequence assessment;
- Atmospheric transport & fate;
- Carbon cycle and climate model physics; and,
- Climate change & model evaluation.

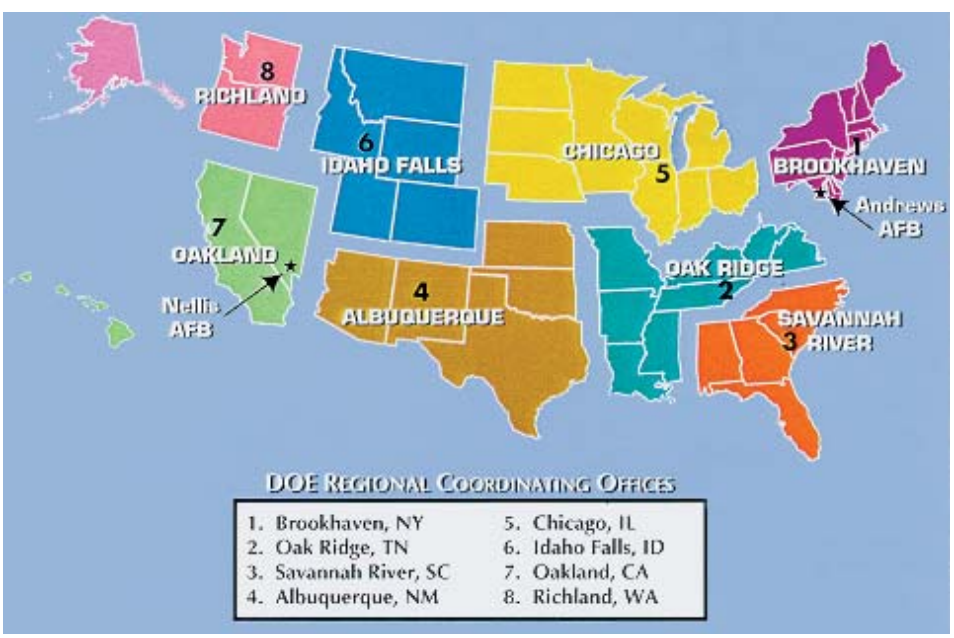


Figure 3-DOE-3. Each of DOE's eight Regional Coordinating Offices maintain a 24-hour response capability for radiological emergencies that may occur in states served by its region.

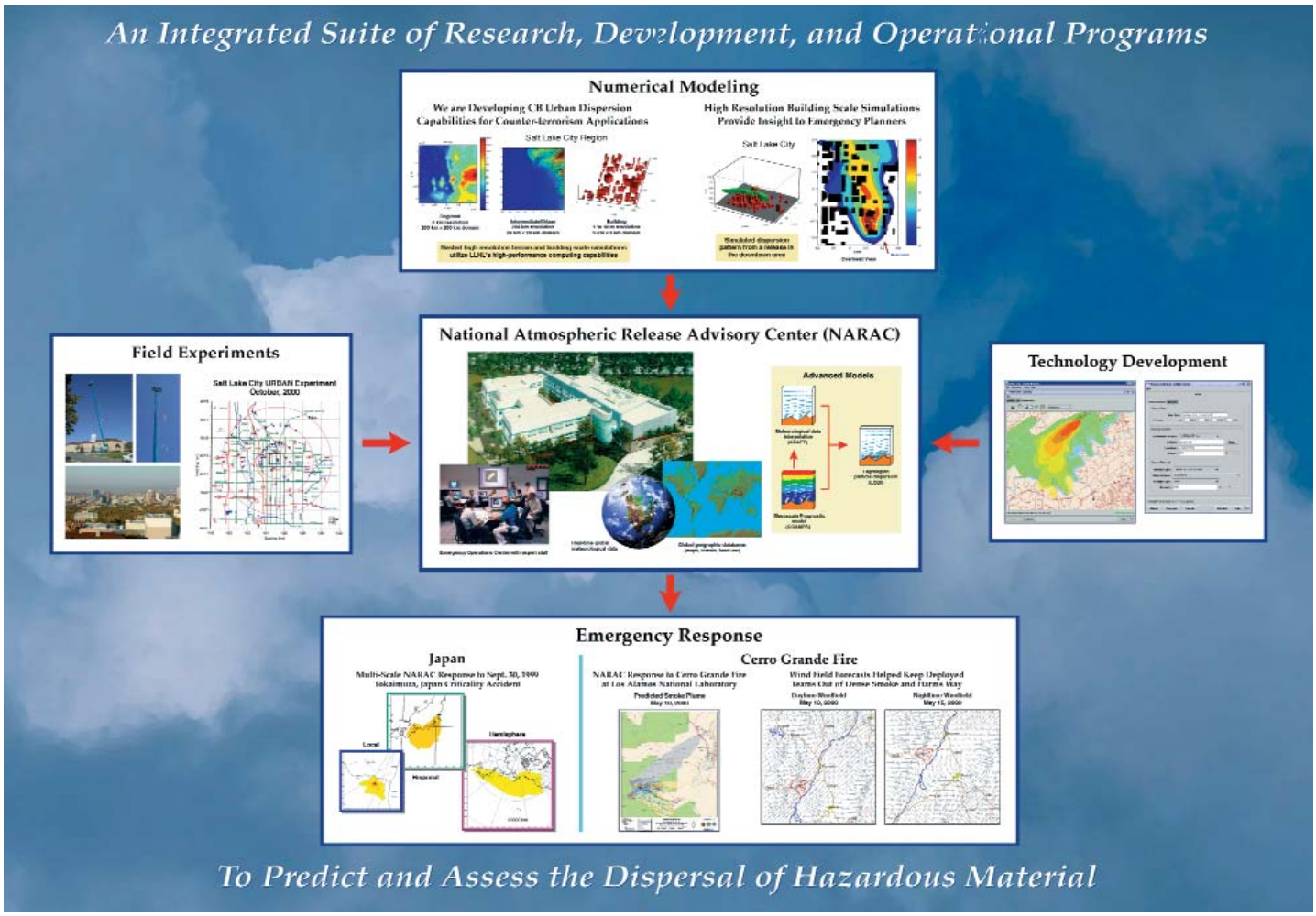
ASD Major Programs Include:

- Program for Climate Model Diagnosis & Intercomparison (PCMDI);
- Institute for Research on Climate Change & Its Societal Impacts (IRCCSI); and,
- NARAC Programs and the National Atmospheric Release Advisory Center (NARAC).

PCMDI's mission is to develop improved methods and tools for the diagnosis, validation, and intercomparison of global climate models, and to conduct research on a variety of problems in climate modeling and analysis (http://www-pcmdi.llnl.gov/).

The mission of IRCCSI is to improve understanding of climate change and its societal impacts, by facilitating collaborations between the University of California-operated DOE laboratories (i.e., LANL, LLNL, and LBNL) and University of California campuses (http://irccsi.llnl.gov/). In particular, DOE plans to try to link the Laboratories' capabilities in high-end climate modeling and climate science with the expertise in regional climate and societal impacts issues resident at the University of California campuses.

NARAC is a centralized emergency response service supporting Federal agencies (http://narac.llnl.gov/). The mission of NARAC is to deliver realistic real-time graphical dose and exposure assessments to emergency decision-makers to assist in the protection of populations at risk for releases of radiological and other hazardous material to the atmosphere. NARAC Programs have developed specific tools to assist elements of the DOE Consequence Management assets, including the Nuclear Emergency Search Team (NEST), Accident Response Group (ARG), Federal Radiological Monitoring and Assessment Center (FRMAC) (http://www.nv.doe.gov/programs/frmac/default.htm), and the Radiological Assistance Program (RAP). Under DOE direction, NARAC supports national special security events, such



as the Winter Olympics in Salt Lake City, UT, in 2002. NARAC also supports DOE sites and Emergency Operations Centers around the U.S. (http://www.nnsa.doe.gov/).

The NARAC central emergency response system consists of automated continuous worldwide meteorological data acquisition, detailed worldwide terrain and geographic mapping databases, a suite of atmospheric dispersion models and source models to assess explosions, fires, spills, or other types of radiological, chemical, biological releases. The system includes a high-resolution, terrain-following, variable-gridded diagnostic meteorological model (ADAPT) and a prognostic model with parameterizations for urban settings (COAMPS) coupled with a generalized Lagrangian particle dispersion model (LODI).

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One of the shared goals of the last three groups is to develop new tools useful to emergency response operations, a key focus area at LLNL since the mid 1970's.

The urban Research & Development effort is developing a coupled suite of multi-scale dispersion models to effectively respond to urban releases. LLNL was a co-leader of the Joint Urban 2003 (i.e., JU2003) field study in Oklahoma City, OK, the largest most complex urban tracer experiment performed to date. The Pacific Northwest National Laboratory (PNNL) was the overall leader, while LLNL, LANL, LBNL were co-Principal Investigators. JU2003 was supported by the Department of Homeland Security (DHS), the Defense Threat Reduction Agency (DTRA) and the Department of Defense (DOD). Data from this study is being used to identify key urban physics and to evaluate NARAC's suite of urban models. A new three-year project has begun to develop a next-generation building-scale computational fluid dynamics model.

Examples of on-going operational integration projects include:

• Integration of mapping systems for field measurement, modeling results, and dose assessment to support DOE Nuclear Incident Response Team (NIRT) capabilities (SNL, RSL) - DOE;

• Enhancement of source term models for radiological, prompt (i.e., blast, thermal, radiation, explosive effects), and chemical-biological releases (SNL) - DOE and DHS;

• Improved dose-response and toxic load models (Edgewood Chemical and Biological Center, U.S. Army) - DHS;

• Development of building infiltration models to predict indoor exposures (with LBNL) - DHS;

• Incorporation of an empirical urban model (Defense Science and Technology Laboratory, UK) - DHS;

• Meteorological and outdoor dispersion modeling for an operational subway system - DHS; and,

• Standardization and integration with the EPA/NOAA CAMEO/ALOHA toxic chemical databases and atmospheric dispersion models - DHS.

LOS ALAMOS NATIONAL LABORATORY (LANL)

Operational

LANL is operated by the University of California (UC) under the responsibility of the DOE Albuquerque Operations Office (ALOO), and is spread across 43 square miles of the Pajarito Plateau at the foot of the Jemez Mountains that extend up to around 900 meters above the plateau. LANL is about 30 miles northwest of Santa Fe in north central New Mexico. The Pajarito Plateau slopes to the east-southeast, dropping 400 meters across the Laboratory, with canyons and mesas running along the slope of the plateau. The broad Rio Grande Valley lies to the east of the laboratory. Los Alamos has a semi-arid, temperate, mountain climate.

The operational meteorological program at Los Alamos operates a network of six towers (ranging in height from 23 meters to 92 meters), a monostatic Doppler SODAR, and three supplemental precipitation stations. Data from four instrumented meteorological towers that are located on the Pajarito plateau drives a diagnostic wind field for the program's plume modeling capability. A fifth tower is located in Los Alamos Canyon to give information on the larger canyons in the area, and a sixth tower is located on top of Pajarito Mountain to measure ambient conditions. The SODAR gives information on winds up to the level of the Pajarito Mountain tower.

More than 100 instruments, consisting of over 20 different types of sensors, are used to collect data throughout the network. Variables measured by the program can be grouped into the categories of wind, SODAR-derived wind, atmospheric state, precipitation-related, radiative fluxes, eddy heat fluxes, subsurface measurements, and fuel moisture. Data collected by the network are checked for quality before its archiving, and raw data and real-time displays of graphs and tables are made available via the Internet.

The LANL Air Quality Group (AQG) provides regulatory and environmental surveillance leadership and services to meet LANL air quality obligations and public assurance needs. The group develops and implements programs to ensure and address institutional compliance with state and Federal laws related to air quality regulations, DOE orders for emergency management, air quality surveillance, dose assessment activities, and community concerns related to air quality issues. The group takes a proactive approach to managing air emissions by providing continuous air monitoring and measurement of external penetrating radiation on-site and off-site.

The group also coordinates LANL activities to ensure full compliance with air emission regulations, providing monitoring and modeling for emergency response, and assisting operating groups in developing and implementing new methods and systems to reduce emissions to as low as reasonably achievable. The monitoring capabilities of the AQG are supplemented by the Atmospheric and Climate Sciences Group (ACSG) field team, which operates various sensor systems including a unique Raman lidar system to obtain images of atmospheric water vapor distributions.

Research

Research within the LANL ACSG supports DOE missions in both the defense and civilian sectors, such as work in the propagation of very-low-frequency sound (i.e., infra-sound) waves. Modeling studies contributed to understanding of propagation and, in particular, sources of "infra-sound". Just as it is possible to infer earthquake epicenters from seismic wave observations, "infra-sound" sources can be inferred from atmospheric observations. This work is an important component of monitoring compliance with the proposed Comprehensive Test Ban Treaty (CTBT). The CTBT work involves a number of organizations within DOE and DOD community, including interactions with other DOE laboratories within the CTBT Research and Development program.

Operational issues involve close work with the Air Force Technical Applications Center (AFTAC) at Patrick AFB, Florida, the DOD organization that handles monitoring systems. In addition, several active international collaborations with other infrasound researchers are ongoing.

The Meteorology Team within the ACSG at LANL conducts analysis and modeling on microscale to mesoscale atmospheric flows and phenomena. In support of the DOE CBNP, a model for

High Resolution and Strong Gradient (HIGRAD) applications is being used to study the effects of radiative heating and shading around groups of buildings. The objective of this study is to determine how these processes may influence the transport of agents within the urban environment. On larger scales, the team is examining the influence of flow merger and urban roughness on the vertical transport and mixing of pollutants with the Regional Atmospheric Modeling System (RAMS) for several western U.S. valleys and basins. This project is in support of the DOE Environmental Meteorology Program (EMP) and for the EPA. As part of the LANL initiative in Coupled Environmental Modeling, researchers within the Meteorology Team are developing a physics-based fire behavior model, FIRETEC, and coupling this model to the HIGRAD atmospheric dynamics code to examine the details of the interaction between local winds and the intense heat generated by wildfires. Also as part of this initiative, a land surface model is being coupled that includes hydrologic processes (i.e., SPLASH) to the RAMS mesoscale model for multi-seasonal simulations of the water resources of the upper Rio Grande Basin.

Meteorology team members are also working on the LANL Urban Security project, which is linking physical and urban growth models to address the needs of cities. In this framework, we are using the RAMS model to provide meteorological fields for use by air chemistry, urban runoff, and other models. The meteorology team within the ACSG conducts analysis and modeling on microscale to mesoscale.

On global scales, research within the LANL meteorological community involves the study of climate change and variability. A major project is the development of a global coupled ocean-atmosphere model sponsored by the DOE Climate Change Prediction Program. The global model being developed consists of a Los Alamos global ocean Global Climate Models (GCMs) Parallel Ocean Program (POP), the Los Alamos sea-ice model (CICE), the National Center for Atmospheric Research (NCAR) Community Climate Model (CCM3), and a "flux coupler" to link the media consistently. The two GCM's and the CICE model exchange heat, momentum, and water mass across the air-sea boundary. A ten-year synchronized simulation revealed the synoptic weather events, seasonal cycles and interannual variations.

Observations related to understanding global climate are the focus of the Tropical Western Pacific (TWP) Program Office LANL, an element of the DOE ARM Program. The TWP Program Office is responsible for the development and operation of the TWP CART locale, a large expanse of tropical-ocean and maritime-continent lying roughly between 10 degrees S and 10 degrees N latitude and from 135 degrees E to 150 degrees W longitude. The maritime continent area is largely in the southwest and the open ocean area in the northeast of the locale. The local climate is characterized by warm sea surface temperatures, deep and frequent atmospheric convection, high rain rates, strong coupling between the atmosphere and ocean, and substantial variability associated with El Niño Southern Oscillation (ENSO) phenomenon.

Scientific questions that need to be addressed in the TWP can be grouped under three main headings:

•. Radiation budget and cloud forcing;

- Water and energy budgets; and,
- Ocean-atmosphere interactions.

The program supports a variety of operations at LANL. The primary client of the program is the Emergency Management Group, for which the program provides a plume modeling capability. Other clients use the program's data for such activities as operations and planning, hazard and accident analyses, environmental studies, support for experiments, compliance, and documentation.

NEVADA TEST SITE (NTS)

Operational

The NTS is managed and operated by the National Nuclear Security Administration/Nevada Site Office (NNSA/NSO). The NTS has been the Nations' underground nuclear weapons testing facility and is now used to support sub-critical experiments and other national defense missions of the U.S.. The NTS occupies 1,350 square miles of south central NV and is approximately 75 miles northwest of Las Vegas, NV. The topography of the NTS is complex with a system of dry lakebeds and mountains. Elevations range from nearly 2,700 feet (ft) above mean sea level (MSL) to 7,600 ft MSL. The climate is arid.

Meteorological services are provided to NNSA/NSO by components of NOAA. NOAA has had a presence on the NTS for more than 45 years through the implementation of Interagency Agreements (IA). During this time, NOAA personnel have built a solid technical reputation in meteorological operations and emergency response. Presently, NOAA support is provided by Air Resources Laboratory Special Operations and Research Division (ARL/SORD) recognized for its expertise in the transport, dispersion, and deposition of radioactive and toxic materials (Figure 3-DOE-4). ARL/SORD has developed a rapid emergency response capability for the

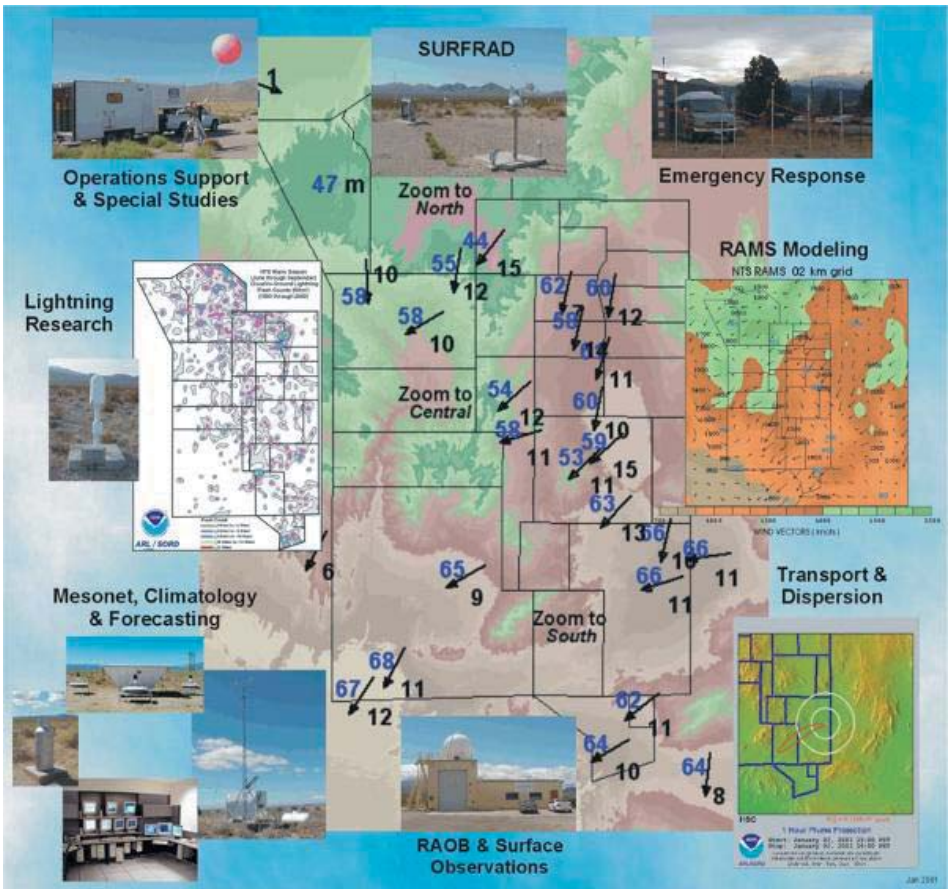


Figure 3-DOE-4. Air Resources Laboratory (ARL)/Special Operations and Research Division (SORD) conducts basic and applied research on problems of mutual interest to National Oceanic and Atmospheric Administration (NOAA) and Department of Energy (DOE), that relate to the Nevada Test Site (NTS), its atmospheric environment, and its emergency preparedness and emergency response activities.

unlikely occurrence of an accidental release of radioactive or hazardous material into the atmosphere.

ARL/SORD provides full meteorological support to all NNSA/NSO operations on and off the NTS. Meteorology plays a key role in environmental, safety, and health responsibilities of NNSA/NSO. The ARL/SORD staff is responsible for conducting a modern program in support of nuclear and non-nuclear projects authorized by NNSA/NSO. Furthermore, the mission of ARL/SORD involves technical support to the emergency preparedness and response activities of NNSA/NSO. ARL/SORD supports a comprehensive meteorological program on the NTS, and provides meteorological and climatology services required in supporting the NNSA/NSO and contractor programs at the NTS, and elsewhere, as necessary.

Personnel at ARL/SORD also consult with senior scientists and engineers at the DOE National Laboratories, NASA, private contractors, Desert Research Institute (DRI), United States Geological Service (USGS), United States Forest Service (USFS), and other NOAA laboratories.

ARL/SORD operates and maintains a large meteorological monitoring network (MEDA) to characterize the meteorology and climatology of the NTS. This network consists of 29, 10-meter towers and 2, 30-meter towers. Wind direction and speed is measured at the 10-meter level on all the towers and temperature and relative humidity is sampled at the 2-meter level. Data from these towers are transmitted via microwave radio to a central processor that checks the data, creates data files, and archives the data every 15 minutes. The data files are accessed by microcomputer to create graphics products for operational use and for immediate display at 15-minute intervals. The MEDA system was upgraded in 2004 to include sonic anemometers.

SORD also operates two, 915MHz vertical profilers on the NTS. One tower is located in the middle of Yucca Flat and the other tower is located at the Hazardous Materials Spill Center (HMSC) in Frenchman Flat near Mercury, NV. In addition, a NOAA full surface radiation (SURFRAD) budget station is operated and maintained at the Desert Rock Meteorological Observatory (DRA) located in the southern part of the NTS. Upper-air soundings are taken twice daily, at 00 and 12 Universal Time Coordinated (UTC) from the DRA facility. ARL/SORD also operates mobile upper-air sounding systems and mobile pilot balloon (PIBAL) equipment to support special projects requiring winds aloft data in real-time.

Large-scale meteorological data and National Center for Environmental Predictions (NCEP) weather forecast products are received via AWIPS, or from the University Center for Atmospheric Research (UCAR) and ARL-Silver Spring, MD. Weather products supplied to DOE contractors, the National Laboratories (e.g., SNL, LANL, and LLNL), the NWS, and Nellis AFB, include real-time cloud-to-ground lightning flash graphical products and local forecast products. Furthermore, a three-tiered lightning alert and warning procedure has been implemented as part of the NTS Integrated Safety Management program.

ARL/SORD has also implemented the RAMS model for the NTS and Southern Nevada. This model predicts boundary layer airflow and precipitation over complex terrain. The RAMS code accesses the NCEP predictive

model outputs and is run twice daily at the University of Nevada at Las Vegas (UNLV) Supercomputer Center on a daily basis. In addition, the NOAA HYSPLIT/HARM dispersion model has been installed on microprocessors in the SORD Meteorological Assessment Center.

ARL/SORD provides meteorological monitoring support and project-specific weather forecast services to NEST, FRMAC and ARG activities. Monitoring support includes surface and upper-air data collection and analysis. Weather forecast service entails maintaining a constant weather watch for conditions that might impact NEST, FRMAC, or ARG operations and personnel, issuing site-specific mesoscale wind, stability, and weather forecasts, aviation weather support, and providing consultation to the On-Scene Commander (OSC) and to National Laboratories personnel. ARL/SORD maintains a web site (www.sord.nv.doe.gov) that includes graphical products that display current meteorological conditions on and around the NTS, including data from ARL/SORD vertical profilers, climatology data, cloud-to-ground lightning information and time-relevant plume transport and dispersion calculations.

Research

Both basic and applied research is carried out on problems of mutual interest to DOE and to NOAA. Emphasis is on the maintenance of meteorological support to national defense projects and to the stewardship of nuclear weapons. These capabilities focus on those facets of meteorology having a direct bearing on the transport, dispersion, deposition (i.e., fallout), and resuspension of radioactive and/or toxic materials. Other research includes documentation and study of extreme precipitation events, desert thunderstorms, cloud-to-ground lightning, and environmental issues related to air quality and visibility. In addition, the SORD program serves as a test bed for advanced NOAA mesoscale prediction models.

A NOAA Climate Reference Station was installed at the Desert Rock Meteorological Observatory in April 2004.

OAK RIDGE NATIONAL LABORATORY

OAK RIDGE RESERVATION (ORR)

Operational

The ORR is home to four DOE/NNSA sites: Oak Ridge National Laboratory (ORNL), the Y-12 National Security Complex, the East Tennessee Technology Park (ETTP, formerly K-25 Site), and the Oak Ridge Institute for Science and Education (ORISE). Managed by the Oak Ridge Operations Office (OROO), the ORR encompasses nearly 100 square miles of hilly and heavily vegetated terrain in eastern Tennessee.

Formerly known as the Oak Ridge Y-12 Plant, and constructed in the early 1940's as part of the Manhattan Project to manufacture nuclear weapons components, the Y-12 National Security Complex (NSC) has now assumed a national security role under NNSA. Y-12 is an 811-acre facility located within the city limits of Oak Ridge, TN, 10 miles from the ORNL and 12 miles from the ETTP, once known as the Oak Ridge Gaseous Diffusion Plant.

Currently operated by BWXT Y-12, the national security programs at Y-12 include manufacturing and reworking nuclear weapon components, dismantling nuclear weapon components returned from the national arsenal, serving as the nation's safe, secure storehouse of special nuclear materials, providing the U.S. Navy with safe, militarily effective nuclear propulsion systems, and reducing the global threat from terrorism and weapons of mass destruction. In early 2004, the Y-12 NSC received, stored and secured a shipment of Libyan nuclear materials.

Meteorological network systems, which support day-to-day operations, are managed and operated at the three main sites by the University of Tennessee (UT)/Battelle, BWXT Y-12 and Bechtel Jacobs Company. These network systems provide data that support environmental management (permitting, facility siting and environmental impact assessment), facility safety (safety analyses), emergency management (hazards and consequence assessment), operations (work planning) and substantial research.

The BWXT Y-12 meteorological program is operations-, environment- and safety- oriented. Y-12 is located in the narrow Bear Creek Valley, and it is bordered by two SW to NE oriented ridges, mostly covered with mature pines and hardwoods. Two meteorological towers have long formed the basis for the meteorological program - a 100-meter tower, instrumented at 10-, 30- and 100-meters, located on the valley floor at the East end of Y-12, and a 60-meter tower, instrumented at 10-, and 60-meters, located on a ridgeline at the West end. In 2003, the data acquisition system was upgraded to an Environmental Systems Corporation (ESC) Windows-based software package, accessing via Ethernet the ESC 8832 data loggers at the towers. This data acquisition package is widely used in air pollution monitoring and in other environmental compliance applications.

Given the complex terrain setting of the Y-12 NSC, a REMTECH PA-2 sodar is used to characterize the winds from 50-meters, extending above the surrounding ridges to a height of 500-meters. Redundant Windows XP polling computers collect 1-hour average sodar data, plus 1-hour, 15-minute, and 1-minute tower data. Displays of the 15-minute data are available in the operations center, in the emergency

centers (including the State EOC), and on an internal web page for general use. For real-time emergency response modeling purposes, 15-minute data is also routed to the NARAC meteorological database, and to a specially-formatted file on the Y-12 EOC modeling computers. There, it is accessible by the local chemical model, CHARM®, a commercially available 3-D grid model with an extensive chemical database and source term modeling features. For most other modeling needs, the NARAC iClient model is used at Y-12, where the ridge-valley and generally complex terrain setting has represented a prototype test and demonstration site for 3-D wind field and terrain models.

There is no on-site weather forecasting service at Y-12, but since it is in the city limits of Oak Ridge, representative forecasts are readily available from the local media, the national network services, and the Internet. Local severe weather advisories and warnings are issued by the nearby NWS Office at Morristown, TN, and they are received and disseminated by the Plant Shift Superintendent's (PSS) Office at Y-12. Also available to the PSS is a subscription weather and doppler radar service, as well as lightning detection and prediction equipment. The Y-12 Meteorologist and a Systems (Hardware/Software) Engineer maintain the program, train and assists others, as needed.

The meteorological data acquisition program at ETTP has two main towers. K-1209 is 60 meters high while K-1208 is 30 meters in height. In addition, two 10-meter supplemental towers are still operating. Lastly, a NEXRAD radar system, and The Weather Channel (TWC) are available to each of the control rooms and emergency response facilities.

The data acquisition program at the ORNL consists of three (two 30-meter and one 100-meter) meteorological towers. Meteorological data is fed to an ORNL central computer system for analysis and dissemination.

Research

NOAA Air Resources Laboratory/Atmospheric Turbulence and Diffusion Division (ARL/ATDD) is located in Oak Ridge near the ORR. The primary mission of ATDD is atmospheric research. Substantial research programs at ATDD are undertaken with the assistance of staff from ORISE/Oak Ridge Associated Universities (ORAU) and scientists from other national laboratories and organizations in the U.S. and abroad. ARL/ATDD also works closely with the ORAU to enhance educational opportunities in atmospheric science.

ARL/ATDD research attention is focused on the physics of the lower atmosphere, with special emphasis on the processes contributing to atmospheric transport, dispersion, and air-surface exchange, and on the development and improvement of predictive capabilities using the results of this research. Many other projects are underway such as surface energy balance and CO2 exchange studies and long-term studies of CO2 exchange aimed at process-level understanding.

Operationally, ARL/ATDD personnel provide meteorological consultation and supplemental data for air quality analyses, environmental reports, and hazard assessments and consequence assessments. Local climatology data are routinely collected and distributed. Under NOAA funding, ARL/ATDD operates a regional network of 15 towers ranging from the Cumberland Mountains (middle Tennessee) to the Smoky Mountains on Tennessee's eastern border. Wind, temperature, and precipitation data are recovered every 15 minutes by telemetry and made available to users.

ARL/ATDD incorporates NWS forecast products into the high-resolution, regional, meteorological model (i.e., RAMS) to produce twice daily 12-hour, 24-hour, and 36-hour predictions of surface winds for eastern Tennessee, and transport trajectory predictions for the ORR.

PANTEX PLANT

Operations

The Pantex Plant covers 15,977 acres and is located 17 miles northeast of Amarillo, TX, in Carson County. The Plant was a World War II munitions factory and was converted to a nuclear weapons assembly facility in 1951. Today, it is the nation's only assembly/disassembly facility supporting the nuclear weapons arsenal. Pantex Plant is a government-owned, contractor-operated facility. DOE oversees operation of Pantex Plant through the Amarillo Area Office (AAO), which reports to the Albuquerque Operations Office. Mason and Hanger Corporation had been the operating contractor since 1956. On February 1, 2001, BWXT Pantex has assumed the Pantex contract.

The Plant is composed of several functional areas, commonly referred to as numbered zones. These include a weapons assembly/disassembly area, a weapons staging area, an area for development of experimental explo-

sives, a drinking water treatment facility, a sanitary wastewater treatment facility, and vehicle maintenance and administrative areas. Other functional areas include a utility area for steam and compressed air, an explosive test-firing facility, a burning ground for thermally treating explosive materials, and landfills. Overall, there are more than 700 buildings at the Pantex Plant.

The Environmental Protection/Restoration Department (EP/RD) of the Environment, Safety and Health Directorate is tasked with the quality assurance program for the meteorological data captured by the one on-site two-level tower located in the northeast corner of the Plant site. The data from this tower (i.e., 10-meters and 60-meters) are collected and used by the DOE NARAC site workstation, located in the Plant EOC. These data are collected and archived as 15-minute averages plus maximum and minimum values for each 15-minute period. They are primarily used for input to the NARAC emergency response models that could be used for off-normal events involving radionuclides. Annual dispersion model calculations of off-site radiation doses from on site sources, required by 40 CFR 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAP), are accomplished by the EP/RD. EP/RD uses the EPA-approved CAP88-PC atmospheric transport and dispersion model and the Pantex meteorological tower data processed into the STAR format. This department also maintains the Pantex Plant climatology database.

Meteorological tower data is also used by the Risk Management Department for plume dispersion modeling applied to the Plutonium Dispersal Consequence Analysis for the Basis for Interim Operations (BIO) validation and upgrade reports, other operations directives, and other safety analyses.

Routine preventive maintenance on the meteorological instruments as well as calibration and certification are done semi-annually by the U.S. Bureau of Land Management (BLM). The BLM maintenance depot at Boise, Idaho performs similar work for the U.S. Forest Service's own meteorological towers instruments. This work is done under a contract administered by the Pantex Emergency Management Department. The BLM Idaho depot also handles emergency repairs and replacement of sensors. Temperature and wind sensors are replaced semi-annually with calibrated and certified sensors. The barometer is replaced annually. During the semi-annual preventive maintenance visits all of the other meteorological instruments are replaced by the BLM technician with rebuilt/refurbished, calibrated equipment, from the Idaho depot. The maintenance check also includes the telephone line, modem, and backup power supply.

As a result of a FY 2000 project meteorological tower data is now displayed on the Pantex Plant Intranet for use by Plant personnel. During FY 2001, the potential for replacing the existing wind sensor on the meteorological tower with a three-dimensional wind sensor was evaluated. In addition, replacing/upgrading the NARAC computer and software located at the base of the tower that feeds data into the NARAC Site System in the EOC was also considered.

Research

There are no current or projected supporting meteorological research activities planned at the Pantex Plant.

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE (RFETS)

Operational

The RFETS is managed by the Rocky Flats Operations Office (RFOO) and is located approximately 16 miles northwest of downtown Denver, CO. One of the smaller DOE sites, the facility occupies a 10 square mile area along the foothills of the Rocky Mountain Front Range.

A 61-meter meteorological tower at the west-end of the site continuously monitors meteorological conditions at surface, 10-meters, 25-meters, and 60-meters above ground level. The data are analyzed, quality assured, and assembled into data sets for use in atmospheric modeling, climatology, and other analyses at the site. Data from the 61-meter and 10-meter towers are also transmitted back to the main site every 15 minutes by telemetry for use in emergency response modeling. The Regional Atmospheric Response Center (RARC) conducts meteorological activities associated with emergency preparedness and response at the site. An upper air remote sensing Sound Detection and Ranging/Radio Acoustic Sounding System (SODAR/RASS) continuously monitors winds, temperatures, and atmospheric stability above the RFETS site.

Through a cooperative agreement with the Colorado Department of Public Health and Environment (CDPHE), meteorological data are transmitted to the site from five surface meteorological stations by telemetry that form a ring around the site perimeter. Another cooperative agreement with NOAA provides near real-time data from multiple monitoring sites throughout the Denver metropolitan area. These data are all received, quality assured, and combined into a three-dimensional observation set for emergency response modeling every 15 minutes, 24 hours per day.

The RARC provides 24-hour consequence assessment support for any unplanned radiological or chemical releases from the site. The Center responds with customized weather forecasts, plume projections, and dose modeling results that lead to event

classifications and protective actions for on-site and off-site populations. RARC also conducts specialized consequence assessments in support of emergency preparedness, hazard assessments, and risk assessments for RFETS. Weather forecasts are provided for severe weather events, such as winter storms, windstorms, and severe thunderstorms.

A customized modeling system has been developed and implemented at RFETS to predict the pathway and impacts from any radiological emergency at the site. Called the Computer-Assisted Protective Action Recommendation System (CAPARS), the new capability addresses the need for fast, accurate plume predictions in a complex atmosphere.

CAPARS provides a variety of plume, weather, hazard, and related products with the accuracy and speed needed for response to an emergency at RFETS. Eleven integrated major subsystems form the overall CAPARS capability.

The State of Colorado has formally accepted the CAPARS modeling system for emergency response and planning applications at RFETS. A specialized planning version of the CAPARS system has been developed, implemented, and applied for emergency planning at the RFETS. Called the TRAC Risk Assessment/Hazards Assessment Model, the capability is designed to support hazards and risk assessments for RFETS and to form the basis for an evaluation of the size and shape of the Emergency Planning Zone (EPZ) surrounding RFETS.

Research

There are no current or projected supporting meteorological research activities planned at RFETS.

SANDIA NATIONAL LABORATORY (SNL)-ALBUQUERQUE

Operational

The DOE Kirtland Area Office (KAO) manages SNL in Albuquerque, NM, located between the Rio Grande Valley and Manzano Mountains. SNL covers approximately 80 square miles of flat to mountainous arid terrain. Meteorological Programs at SNL include both support and research activities.

Meteorological services and support are provided through the EOC in the Laboratory Services Division (LSD). The mission is to provide meteorological support for various operations including:

- Emergency response;
- Environmental surveillance and characterization; and,
- Regulatory compliance.

The monitoring network consists of six, 10-meter and two, 60-meter towers used to measure wind direction and speed, ambient temperature, and relative humidity. There are also three precipitation gauges, two barometric pressure sensors, and one solar radiation pyranometer in the network.

Research

Key research activities are provided through the Energy and Critical Infrastructure Center in the Energy, Information, and Technology Division. SNL scientists are involved in the ARM program and the Surface Heat Budget of the Arctic Ocean (SHEBA). The ARM project is a combined measurement and modeling program. The goal is to gain a better understanding of clouds and their effect on atmospheric radiation, with the final goal of developing better climate models. The SHEBA program addresses the interaction of the surface energy balance, atmospheric radiation and clouds over the Arctic Ocean.

SAVANNAH RIVER SITE (SRS)

Operational

The SRS is under the responsibility of the Savannah River Operations Office (SR) and operated by the Westinghouse Savannah River Company (WSRC). SRS is located in southwestern South Carolina, along the banks of the Savannah River. The SRS covers an area of approximately 300 square miles and is thickly forested with pine trees. There are also several small streams, a large swamp, and two reservoirs built as cooling ponds for nuclear plant reactors. The topography of SRS is characterized by gently rolling hills with an adjacent flood plain near the Savannah River. The climate at SRS is typical of the southeastern U.S. with long, hot and humid summers and short mild winters.

The Atmospheric Technologies Group (ATG) of the Savannah River Technology Center (SRTC) has developed and operated a meteorological monitoring and modeling program at the SRS since the early 1970's. This program supports SRS operations in emergency response consequence assessment, weather forecasting, radiological and non-radiological air quality calculations for regulatory compliance, safety analyses, environmental impacts, engineering studies, environmental research and non-proliferation activities.

ATG's meteorological data sources are extensive and quite varied. On-site meteorological data are obtained from a network of eight 200-foot meteorological observing towers located near the major production sites. The instrumentation on these towers includes sensitive bi-directional vanes (i.e.,

bivanes), cup anemometers, resistance thermometers and lithium chloride humidity sensors. Another tower is located at the Central Climatology facility, located near the geometric center of the SRS. It includes like instruments near ground level, 60-ft, 120-ft, and 200 ft. Additional meteorological measurements at the Central Climatology facility include precipitation, evaporation, barometric pressure, soil temperature, solar and long wave radiation. Data are collected with dedicated data loggers at each tower site. Each logger is then polled by a remote computer that, in turn, populates a relational database with meteorological data.

A network of twelve manually-read rain gauges is located throughout the SRS. Additional local upper-air data are collected from a balloon-launched airsonde system and a portable tethersonde system. Portable towers are available for use in case studies.

ATG also has access to local radar data, which is then distributed site-wide via the SRS intranet. Regional, national, and international meteorological data are received from a commercial weather data provider via satellite in real time. The data include surface observations, satellite and radar imagery, and predictive model information from the U.S. and abroad.

In addition, ATG has developed the Weather Information and Display (WIND) System as an automated resource for conducting real-time consequence assessments following unplanned releases of hazardous material. The WIND System is a multi-computer platform network that links the real time meteorological observations and forecasts with a suite of atmospheric and aqueous transport and dispersion models. A rolling 24-hour data file is created from data archived in the meteorological database and disseminated to a pc-based workstations that can operate the WIND System's modeling and display software.

In the mid 1990s, a mutual aid agreement with surrounding counties emergency management agencies was created to install and operate four meteorological towers at nearby chemical plants in support of emergency response activities. Data from these towers are incorporated into the SRS meteorological database, integrated into the 24-hour data file, and made available beyond the SRS firewall for use by the off site partner entities using appropriate WIND System software.

Nearby SRS, two television stations, WJBF and WAGT, have built a new television tower, where SRTC has installed meteorological instrumentation at the 100 ft, 200 ft, and 1000 ft levels. This local television transmitter tower was instrumented with fast response three-dimensional sonic anemometers and optical water vapor and CO2 sensors at 100-ft, 200-ft, and 1,000 ft. Slow response temperature and humidity sensors were also installed at these levels. The data from this tower will provide vital information for both operational emergency response and for the USFS to conduct control burns. It will also provide valuable data for research in the atmospheric boundary layer.

A joint partnership between Westinghouse Electric Company and a local television station provides local Doppler radar data to SRS and the local community in real-time. This provides valuable site specific radar returns to assist in site operations. The data (e.g., static and time lapse - movie - images) are available through the site internal computer network at employees' desktop computers.

ATG utilizes a regional mesoscale model, RAMS, for providing detailed forecast information. Specifically, forecasts out to 24 hours from RAMS are available as input for the predictive component of WIND System models. Transport calculations blend observed meteorological data with RAMS forecasts to make timely and accurate assessments. The grid resolution used in RAMS varies from 2 km for the inner grid (100 km x 100 km centered on the SRS) and 8 km for the outer grid (250 km x 250 km).

The SRS Atmospheric Technology Center provides access to local, national and international meteorological data to provide comprehensive meteorological support for SRS and WFO customers. On a daily basis, ATG provides weather forecasts in support of site operations. Typical customers include waste handling groups where wind and rain forecasts often determine daily activities. Also, ATG supports the U.S. Forest Service (USFS) prescribed burn program and site heat stress program with detailed observations and forecasts. Custom forecasts are also provided to facility and other senior managers to support protective action decisions for severe weather.

Research

There are no current or projected supporting meteorological research activities planned at SRS.

WASTE ISOLATION PILOT PLANT (WIPP)

Operational

The Waste Isolation Pilot Plant (WIPP) is operated by Westinghouse TRU Solutions for the DOE Carlsbad Area Office (CAO). A cornerstone of the DOE national clean-up strategy, the WIPP is designed to permanently dispose of transuranic (TRU) radioactive waste generated by defense-related activities in the Salado salt formation 2,150 feet beneath the surface. WIPP is located in Eddy County in southeast-

ern New Mexico, 26 miles east of Carlsbad, and occupies 16 square miles of a region know as Los Medanos. Geographically, the region is regarded as a relatively flat, sparsely inhabited plateau with little surface water.

The WIPP Environmental Monitoring Section (EMS) performs meteorological monitoring as part of the Nonradiological Environmental Monitoring Program. The primary meteorological station provides measurement of wind direction and speed, temperature at two-meters, 10-meters, and 50-meters, as well as ground level measurements of barometric pressure, relative humidity, precipitation, and solar radiation. The main function of the station is to generate data for operational support, emergency response and regulatory dispersion modeling applications. Parameters are monitored continuously and the data are stored in the Central Monitoring System, a computerized system including automated parameter checks, real-time displays in the Central Monitoring Room, and data archiving. Meteorological data are compiled and distributed to stakeholders, including the NOAA NWS, on a monthly basis.

WIPP also, under a cooperative agreement with the NWS, maintains a Cooperative Weather Observing Station at the Far Field Station. Data from this station are compiled monthly and the Record of Climatological Observations form is submitted to the Weather Forecast Office in Midland, TX. Under the same cooperative agreement, the Midland office is given access to real-time data from the primary meteorological station.

Research

There are no current or projected supporting meteorological research activities planned at WIPP.

WELDON SPRINGS SITE REMEDIAL ACTION PROJECT (WSSRAP)

Operational

The activities associated with Weldon Springs Site Remedial Action Project (WSSRAP) have been completed. The meteorological monitoring program that had operated at the WSSRAP since 1994 was dismantled in 2003.

Research

There are no current or projected supporting meteorological research activities planned at WSSRAP.

YUCCA MOUNTAIN PROJECT (YMP)

Operational

As part of the DOE Office of Civilian Radioactive Waste Management (OCRWM), the Yucca Mountain Project (YMP) studies may eventually support a recommendation of Yucca Mountain for the nation's first geologic repository for spent nuclear fuel and other high level radioactive waste (Figure 3-DOE-5). The current meteorological program within the YMP focuses on environmental compliance and operational health and safety considerations, for both employees and the general public.

As with a number of DOE sites, the Yucca Mountain area is one of complex topography and heterogeneous surface characteristics, creating mesoscale conditions that locally influence on-site weather. The YMP meteorological program, therefore, includes four full stations for measuring atmospheric dispersion and general meteorological conditions, as well as nine precipitation stations. These stations serve to monitor the significant variations in airflow, rainfall, and temperature caused by the area's complex terrain environment. The meteorological stations are key to the thorough monitoring of these variations that is essential for the YMP ongoing commitment to environmental compliance and to the health and safety of employees and the public.

The YMP meteorological program also provides essential data for the studies necessary to evaluate the site's suitability for a potential repository. Should the site be deemed suitable and a repository licensed, built, and operated, water would be the primary means by which radioactive materials could be transported to the accessible environment. Thus, movement of water from the atmosphere to the sur-

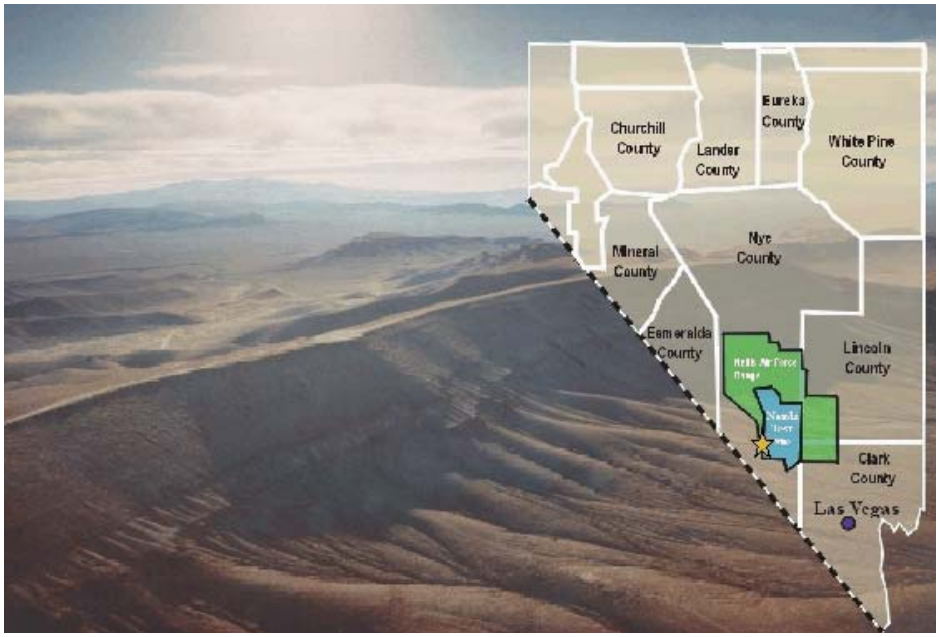


Figure 3-DOE-5. Yucca Mountain (100 miles northwest of Las Vegas, Nevada) is unpopulated land owned by the Federal Government and adjacent to the nation's nuclear weapons test site.

face and on through the mountain is a key concern. The meteorological program provides essential data for the infiltration model of the mountain. Data about precipitation, humidity, evapotranspiration, surface water run-on, solar radiation, air temperatures, and wind patterns all contribute to the overall infiltration model. The model gives special emphasis to the transient, or temporal, versus steady-state rates of water movement through the unsaturated zone of rock at Yucca Mountain. The temporal variation of infiltration may be short term, due to weather fluctuations that drive episodic flow, or much longer term, in periods corresponding to climate change. Data from the meteorological program's ongoing monitoring programs are supplemented by the program's paleoclimatology studies. Together, they provide essential information for the YMP modeling of past, present, and future infiltration rates.

If the potential repository were actually built and operated, continuous meteorological monitoring and analysis would also be essential for the operational facilities on the surface of the mountain, at least until the final closure of the repository. Buildings would be built to withstand the probable maximum flood and wind conditions, and administrative controls would be in place to suspend operations during severe weather conditions. An integral part of the emergency response system would include monitoring the overall environmental situation at the repository site.

In turn, an integral part of the overall environmental monitoring system would be the meteorological monitoring system. This system would collect real-time meteorological information about the site and provide weather forecasting and climatological data. Such data would be essential for management decisions regarding the health and safety conditions for employees and the public.

Research

There are no current or projected supporting meteorological research activities planned at the Yucca Mountain site.

DOE METEOROLOGICAL COORDINATING COUNCIL (DMCC)

Based on a need to facilitate more coordination and cooperation among the meteorological activities at the DOE field offices, the DMCC (i.e., the Council) was established on December 2, 1994. The mission of the Council, now in its eleventh year, is to coordinate meteorological support and research to meet DOE objectives. The objectives of the council are to:

- Promote cost-effective support for all DOE facilities;
- Plan for future needs, requirements, and missions;
- Advocate awareness of atmospheric science applications and benefits to DOE; and,
- Advocate the use of common methods, procedures, and standards.

Council oversight is provided by a steering committee consisting of DOE and NNSA headquarters and field element representatives. Products of the DMCC include evaluations of meteorological requirements contained in DOE orders and guidance documents, site meteorological program peer reviews, and, as needed, customized technical assistance. Assist Visits have been conducted at NNSA/NSO, WIPP, Pantex, DOE/OR and SNL-Albuquerque. Two follow-up assist visits were also conducted at WIPP. Additional assist visits are in the planning stages and will be conducted over the next several years.

The DMCC web page has been broadened and can be accessed at www.sord.nv.doe.gov. The DMCC can also be accessed through the web page of the Subcommittee for Consequence Assessment and Protective Actions (SCAPA).

DEPARTMENT OF HOMELAND SECURITY WEATHER PROGRAMS

The Department of Homeland Security (DHS) has three primary missions: Prevent terrorist attacks within the United States, reduce America's vulnerability to terrorism, and minimize the damage from potential attacks and natural disasters. The department's first priority is to protect the nation against further terrorist attacks. Component agencies will analyze threats and intelligence, guard our borders and airports, protect our critical infrastructure, and coordinate the response of our nation for future emergencies. Besides providing a better-coordinated defense of the homeland, DHS is also dedicated to protecting the rights of American citizens and enhancing public services, such as natural disaster assistance and citizenship services, by dedicating offices to these important missions. DHS has Five Major Divisions, or "Directorates": Border and Transportation Security (BTS); Emergency Preparedness and Response (EPR); Science and Technology (S & T); Information Analysis and Infrastructure Protection (IAIP); Management. Besides the five Directorates of DHS, several other critical agencies folded into the new department or were created: United States Coast Guard; United States Secret Service; Bureau of Citizenship and Immigration Services; Office of State and Local Government Coordination; Office of Private Sector Liaison; and the Office of Inspector General.

On March 1, 2003, the Department of Homeland Security (DHS) assumed primary responsibility for ensuring that emergency response professionals are prepared for any situation in the event of a terrorist attack, natural disaster, or other large-scale emergency. This entails providing a coordinated, comprehensive Federal response to any large-scale crisis and mounting a swift and effective recovery effort. DHS will also prioritize the important issue of citizen preparedness, and educating America's families on how best to prepare their homes for a disaster and tips for citizens on how to respond in a crisis will be given special attention at DHS.

Homeland Security Presidential Directive #5 (HSPD 5), states that "to prevent, prepare for, respond to, and recover from terrorist attacks, major disasters, and other emergencies, the U.S. Government shall establish a single, comprehensive approach to domestic incident management." It also assigns the Secretary of the Department of Homeland Security the role of principal Federal official for domestic incident management. Based on previous Federal guidelines and legal authorities, a number of Federal agencies have responsibilities, depending on the scenario, and each agency has developed or has access to source-term estimates, dispersion modeling, and consequence assessment capabilities to meet their responsibilities. For a domestic incident, these capabilities would be coordinated by the Secretary of the Department of Homeland Security in cases where a Federal response is required and authorized.

Over the coming year, the goal is to develop an all-hazards dispersion support framework, initially based on atmospheric dispersion modeling and consequence assessment, to support the DHS Secretary in his role as principal Federal official for planning, preparing, and responding to domestic incidents. This framework will provide tailored all-hazards dispersion support to DHS and its Homeland Security Operations Center (HSOC). The primary and most urgent objective is to provide the best available information for atmospheric hazard predictions so that DHS can make appropriate emergency response and consequence management decisions. This effort is based on the work and recommendations of the OFCM-sponsored Joint Action Group on the Selection and Evaluation of Atmospheric Transport and Dispersion Models (JAG/SEATD) report, Atmospheric Modeling of Releases from Weapons of Mass Destruction: Response by Federal Agencies in Support of Homeland Security, August 2002, and the National Research Council's (of the National Academies) Board on Atmospheric Sciences and Climate report, Tracking and Predicting the Atmospheric Dispersion of Hazardous Material Releases: Implications for Homeland Security, 2003.

EMERGENCY PREPAREDNESS AND RESPONSE (EPR)

In March 2003, FEMA joined other Federal agencies, programs and offices in becoming the Department of Homeland Security. The new department brings a coordinated approach to national security from emergencies and disasters - both natural and man-made. About 2,600 full-time employees in FEMA are supplemented by more than 4,000 stand-by disaster reservists.

In carrying out its role, FEMA works with all of the agencies to assure that the delivery of meteorology-related information is conducted in keeping with established goals and objectives. As administrator of the National Flood Insurance Program (NFIP), FEMA publishes Flood Insurance Rate Maps for all flood-prone communities, which serve as the official demarcation

for flood risk. FEMA administers the National Hurricane Program and, for regions subject to hurricanes, publishes hurricane evacuation zone maps based on surge model simulation results from the National Weather Service's National Hurricane Center.

FEMA priority interests with OFCM are in supporting the FEMA pre-disaster initiatives and in promoting standards and procedures which will enhance the ability of the Nation to mitigate and recover from emergencies and disasters (Figure 3-DHS-1). These interests extend to national standards for geographic information systems (GIS) used for delivery of meteorological products and services by other agencies. FEMA also actively supports the OFCM-sponsored Working Group for Post-Storm Data Acquisition (WG/PSDA) and the WG/PSDA's efforts to develop a National Plan for Post-Storm Data Acquisition to coordinate and support the collection, by the Federal agencies, of perishable data after major storms. These data have potential applications in post-disaster mitigation activities, the NFIP flood hazard analysis, the FEMA National Hurricane Program hurricane evacuation studies, and other FEMA risk analysis activities, such as the Multi-Hazard Loss Estimation Methodology (HAZUS). The Risk Analysis Branch is the principal contact for hurricane evacuation studies and flood risk analysis as well as the FEMA contact point for meteorology-related matters. For additional information see www.fema.gov.

UNITED STATES COAST GUARD (USCG)

Since March 2003, the Commandant of the Coast Guard reports directly to the Secretary of Homeland Security. However, the USCG also works closely with the Under Secretary of Border and Transportation Security as well as maintain its existing independent identity as a military service. Upon declaration of war or when the President so directs, the Coast Guard would operate as an element of the Department of Defense, consistent with existing law.

Although no U.S. Coast Guard (USCG) cutters or shore units are solely dedicated to meteorology, they collectively perform a variety of functions in support of the national meteorology program. USCG ocean-going cutters and coastal stations provide weather observations to the National Weather Service (NWS). Coast Guard communications stations broadcast NWS marine forecasts, weather warnings, and weather facsimile charts and, also, collect weather observations from commercial shipping for the NWS. The Coast Guard also operates the LORAN C radionavigation system and the Maritime Differential GPS (DGPS) Service. The LORAN C system provides Position, Navigation, and Timing (PNT) information to a variety of navigation and non-navigation users throughout the continental U.S. and Alaska (e.g. radiosondes). The Maritime DGPS Service is an augmentation to the GPS that improves GPS-only accuracy to better than ten meters and provides DGPS coverage to coastal areas of the continental U.S., the Great Lakes, Puerto Rico, portions of Alaska and Hawaii, and portions of the Mississippi River Basin.

Coast Guard operates three polar icebreakers - USCGC POLAR STAR, USCGC POLAR SEA, and USCGC HEALY - to serve our Nation's security, economic, environmental, and scientific interests. These vessels make important marine environmental measurements during dedicated science deployments or in conjunction with other missions.

USCGC HEALY, a new icebreaking research vessel, was delivered to the Coast Guard in November 1999 and conducted successful shakedown tests of the hull, machinery, and scientific equipment during January-August 2000 (Figure 3-DHS-2). The first unrestricted science cruise was conducted in the Eastern Arctic in the summer of 2001. HEALY, has a length of 420 feet, beam of 82 feet, and displaces over 16,000 tons. Scientific sys-

Figure 3-DHS-1. Bay Minette, AL, July 14, 2005. The FEMA mobile Disaster Recovery Center helps applicants with the FEMA recovery process by making it easier for applicants to apply for FEMA aid. It contains phone lines and wireless telecommunications. Many areas of southern Alabama were affected by Hurricane Dennis. FEMA Photo/Mark Wolfe.

Figure 3-DHS-2. USCGC HEALEY, the Coast Guard's new icebreaking research vessel, conducting ice trials.

tems and gear include a bottom mapping multi-beam sonar system; a sub-bottom profiling system; a conductivity-depth-temperature data system; an expendable oceanographic probe system; an Acoustic Doppler Current Profiler; a jumbo coring system; a continuous flow, seawater sampling system; a meteorological measurement system; and a bow tower for clean air experiments. To schedule time on HEALY, see the UNOLS web site, *www.unols.org*. For more information, see the Coast Guard web page for HEALY, *www.uscg.mil/pacarea/healy/*.

USCG conducts the International Ice Patrol (IIP) under the provisions of the International Convention for Safety of Life at Sea (SOLAS). The IIP uses sensor-equipped aircraft to patrol the Grand Banks of Newfoundland to locate and track icebergs which pose a hazard to North Atlantic shipping. Direct observations are supplemented and extrapolated using a numerical iceberg drift and deterioration model. IIP determines the geographic limits of the iceberg hazard and, twice daily, broadcasts iceberg warning bulletins and ice facsimile charts which define the limits of the iceberg threat during the iceberg season (spring and summer). IIP annually archives data on all confirmed and suspected icebergs, and forwards these data to the National Snow and Ice Data Center. These data can be accessed via the IIP web page *www.uscg.mil/lantarea/iip/home.html*. Archived data contains all iceberg sighting data along with the last model-predicted position of each berg.

The Coast Guard participates with the Navy and NOAA in conducting the National Ice Center, a multi-agency operational center that produces analyses and forecasts of Arctic, Antarctic, Great Lakes, and coastal ice conditions.

The Coast Guard also collaborates with NOAA in operating the National Data Buoy Center (NDBC) which deploys and maintains NOAA's automated network of environmental monitoring platforms in the deep ocean and coastal regions. Five Coast Guard personnel fill key technical and logistics support positions within NDBC. Coast Guard cutters support the deployment and retrieval of data buoys, and provide periodic maintenance visits to both buoys and coastal stations, expending approximately 180 cutter days annually. Coast Guard aircraft, small boats, and shore facilities also provide NDBC support.

Meteorological activities are coordinated by the Ice Operations Division of the Office of Aids to Navigation at Coast Guard Headquarters. Field management of Coast Guard meteorological support services is accomplished at the Coast Guard Area and District levels.

DEPARTMENT OF THE INTERIOR WEATHER PROGRAMS

The Department of the Interior (DOI), is the nation's principal conservation agency, charged with the mission "*to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.*" The following operational and research programs contribute to the Federal Meteorological Plan.

UNITED STATES GEOLOGICAL SURVEY (USGS)

WATER DATA

The USGS's Water Resources Discipline (WRD) collects streamflow, precipitation, water quality, ground-water level, and other water resources and climatological data as part of a national network and for a number of projects concerning rainfall runoff, water quality and hydrologic processes. Currently, the USGS collects hydrologic and meteorological data from about 11,000 surface-water sites, precipitation data from more than 1,200 sites, ground-water level data from more than 23,000 sites, and water quality data from more than 8,400 surface-water, ground-water, and precipitation sites.

Data collected at USGS sites are transmitted from approximately 8,100 remote Data Collection Platforms (DCPs). The data are transmitted to Wallops, Virginia, via GOES and rebroadcast to a domestic communication satellite (DOMSAT). Data are received from the DOMSAT by local readout ground stations (LRGS) procured by USGS. The USGS currently operates 25 LRGS which provide near-real-time data to the USGS's computerized National Water Information System (NWIS). Data from over 1,800 additional sites are transmitted via other telemetry (mostly telephone). Near-real-time streamflow data and ancillary information are provided to National Weather Service River Forecast Centers for about 3600 river forecast points (Figure 3-DOI-1).

The USGS also collects precipitation samples in a number of studies for the determination of atmospheric contribution to the chemical constituent loads to runoff, and for defining the effect of atmospheric deposition on water quality and the aquatic environment.

The USGS serves historical and real-time water resources data on the Internet at its NWIS Web site (http://waterdata.usgs.gov/nwis/).

SNOW AND ICE STUDIES

USGS scientists are cooperating with scientists at the University of Washington, Seattle, to improve hydrologic runoff modeling of the snow pack in the Pacific Northwest through the application of data assimilation techniques. The assimilation uses passive microwave observations from the Advanced Microwave Scanning Radiometer, AMSR-E, and numerical integration of Maxwell's equations constrained by a snow pack model to determine the distribution of snow water equivalent across select drainage basins. Then the UW Variable Infiltration Capacity (VIC) model calculates the subsequent runoff, which is compared to USGS discharge measurements. If the calculated runoff is not within a specified amount of the measured runoff, the assimilation technique adjusts the snowpack characteristics and another iteration is carried out.

USGS, in cooperation with BLM, is using a variety of remote sensing data to monitor the rapid wastage of the piedmont lobe of Bering Glacier, Alaska. Landsat, Radarsat, ICESat, and Ikonos observations show that

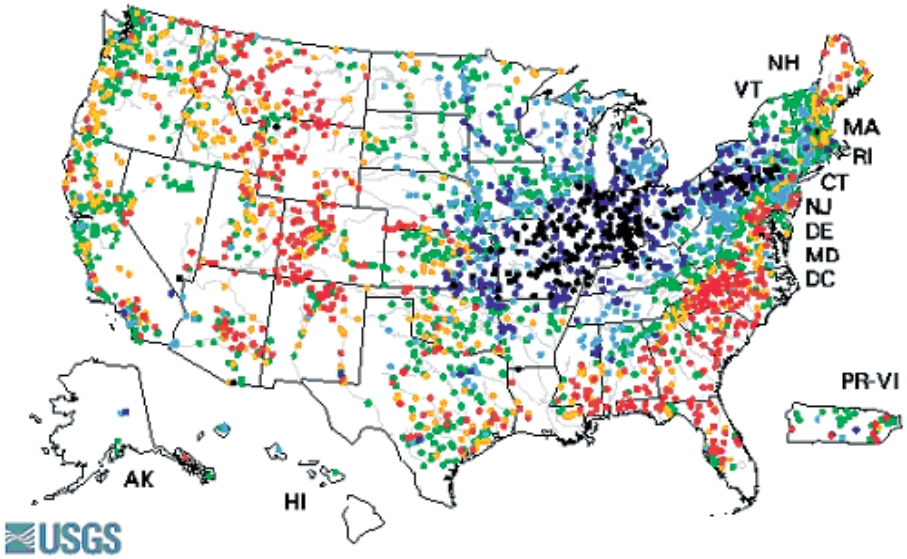


Figure 3-DOI-1. Sample USGS Water Watch map of real-time streamflow compared to historical streamflow for the day of the year. Source: USGS Website: *http://water.usgs.gov/waterwatch/*

Bering Glacier is retreating rapidly and thinning in an accelerating retreat from an advanced position that resulted from a major glacial surge in 1993-95. The satellite data and ground-based observations have been combined to determine the surface flow velocities and calving rates of the glacier, and to monitor the expansion of Vitus Lake and Berg Lake, two large lakes whose boundaries include the glacier terminus. The rapid change in glaciation is having a large impact on nearby terrestrial and aquatic ecosystems.

CLIMATOLOGICAL RESEARCH

USGS also carries out research in climate change, regional hydrology, the carbon cycle, coastal erosion, volcanic activity, and glaciology. As part of its glaciology program, the USGS maintains an observation program on three benchmark glaciers representative of different climactic zones of the western U.S., one in Washington, one on the south coast of Alaska and one in the interior of Alaska. At each glacier, the program measures the winter snow accumulation, summer snow and ice ablation, air temperature, and runoff in the glacier basin. Begun in 1959, this is the longest such record in North America. Analysis of this record is providing a greater understanding of the climate variability and its effects on water resources of the western U.S.. The record clearly shows the effects of changing winter precipitation patterns associated with atmospheric conditions in the northeast Pacific Ocean, including El Niño - La Niña events and the Pacific Decadal Oscillation.

To augment its glacier monitoring efforts, the USGS is using National Systems data to measure fluctuations of glaciers in Alaska, Washington, and Montana. Mountain glaciers are ideal subjects for these systems because they are remote, have an appropriate space scale, and require infrequent but repetitive observations. The observations have established a baseline of regional glacial conditions. The resulting and on-going archive of observations is now 5-years long and is being used to determine recent trends in glacier size and terminus location. In addition, techniques have been developed to generate derived products that provide critical glacial parameters, including DEMs, equilibrium line altitudes, and ablation rates. These products are already being incorporated into a glacial runoff model of the South Cascade Glacier, Washington, where they are proving to be a valuable source of otherwise unavailable data.

GEOMAGNETIC DATA

The Geomagnetism Program (http://geomag.usgs.gov) of the USGS Central Region Geohazards Team provides real-time, ground-based measurements of the Earth's magnetic field, which are an important contribution to the diagnosis of conditions in the near-Earth space environment of the sun, the solar wind, the magnetosphere, the ionosphere, and the thermosphere. During geomagnetic storms, brought about by the complex interaction of the Earth's magnetic field with that of the Sun's, both high- and low-frequency radio communications can be difficult or impossible, global positioning systems (GPS) can be degraded, satellite electronics can be damaged, satellite drag can be increased, and astronauts and high-altitude pilots can be subjected to enhanced levels of radiation.

Ground-based geomagnetic observatory data are complementary to those collected by space-based satellites; indeed, most of the hazardous effects on technological systems brought about by magnetic storms occur at or near the Earth's surface. Therefore, the Geomagnetism Group monitors the surficial magnetic field by operating 14 magnetic observatories in the U.S. and its Territories. The data from these observatories, plus 15 foreign observatories, are transmitted to the Group's headquarters in Golden, Colorado, where they are processed and analyzed. Data are then transmitted to the Space Environment Center (SEC) of the National Oceanic and Atmospheric Administration (NOAA) and to the U.S. Air Force's (USAF) Weather Agency at Offutt Air Force Base, Nebraska.

USGS observatories are operated in cooperation with Intermagnet (www.intermagnet.org), an international consortium overseeing the operation of nearly 100 geomagnetic observatories distributed around the globe. The USGS Geomagnetism Program is also an integral part of the National Space Weather Program (http://nswp.gsfc.nasa.gov).

VOLCANOLOGY AND VOLCANIC ASH PLUMES

Through its Volcanic Hazards Program, the USGS is responsible for monitoring volcanoes in the U.S. and issuing eruption forecasts and notifications. The USGS participates in the Working Group for Volcanic Ash (WG/VA) of the OFCM. This working group is preparing a National Volcanic Ash Operating Plan for Aviation. The purpose of the plan is to provide operational guidance by documenting the required procedures and information products of the government agencies responsible for ensuring safety of flight operations when volcanic ash has been erupted into the atmosphere. The agencies involved are the USGS, Federal Aviation Administration (FAA), National Oceanic and Atmospheric Administration (NOAA), and the U.S. Air Force. Timeline for completion of the plan is FY 2006.

The OFCM helps to administer funding from the FAA to the USGS to improve aviation safety through expanded volcano monitoring in Alaska, where many historically active volcanoes underlie the heavily traveled air routes of the North Pacific region. Over the past decade, with FAA support, the USGS's Alaska Volcano

Observatory (AVO) has installed seismic networks at approximately two dozen volcanoes in the Aleutian Islands, bringing to 30 the number of Alaska's volcanoes under continuous real-time geophysical surveillance. Data and information from the AVO monitoring activities are integrated directly into the regional operational activities of the FAA, DOD, and NOAA/NWS to provide warnings for pilots and aircraft operators in the Alaskan region.

The U.S. has experienced significant levels of volcanic activity recently. Augustine Volcano, located near Anchorage, Alaska, erupted from January to April 2006, and has not yet settled back to quiescence. AVO mounted a 24/7 monitoring response to characterize ash-cloud hazards to aviation and worked closely with the National Weather Service to provide ash-fall information to the public. AVO also has continued to closely monitor Veniaminoff volcano in Alaska, which has been erupting intermittently since 2002. Mount St. Helens, Washington, reawakened in September 2004, from 18 years of quiescence. The eruption has largely consisted of the extrusion of lava with activity confined to the summit area. However, periodic explosions have erupted ash to heights as great as 30,000 feet above sea level. USGS, NWS, and FAA have worked together to develop procedures and protocols to handle an erupting volcano situated between two major metropolitan centers.

The Volcano Hazards Program posted new pages on its website, devoted to practical guidance for dealing with ash hazards to transportation, communications, agriculture, water supplies, etc. See http://volcanoes.usgs.gov/ash.

Recognizing that many potentially dangerous U.S. volcanoes have inadequate or no ground-based monitoring, the USGS recently evaluated U.S. volcano-monitoring capabilities and published "*An Assessment of Volcanic Threat and Monitoring Capabilities in the United States: Framework for a National Volcano Early Warning System (NVEWS)*" (online at http://pubs.usgs.gov/of/2005/1164/).

Results of the NVEWS volcanic threat and monitoring assessment are being used to guide long-term improvements to the national volcano-monitoring infrastructure operated by the USGS and affiliated groups. The most threatening volcanoes, those near communities and transportation infrastructure (ground and air) and with a history of frequent and violent eruptions, need to be well monitored in real time with an extensive suite of instrument types to detect the earliest symptoms of unrest and to reliably forecast behavior of the volcano. Waiting until unrest escalates to augment monitoring capabilities at these high-threat volcanoes puts people (including scientists in the field) and property at undue risk. Remote, isolated, or less frequently erupting volcanoes that nevertheless can pose hazards to air-traffic corridors require sufficient monitoring capability with ground-based instruments to detect and track unrest in real-time so that other agencies responsible for enroute flight safety can be kept apprised of the potential for explosive, ash-cloud-forming eruptions.

BUREAU OF LAND MANAGEMENT (BLM)

The BLM is one of five Federal Land Management agencies which have centralized Wildland fire weather operations at the National Interagency Fire Center (NIFC), in Boise, Idaho. The BLM's Initial Attack Management System (IAMS) was designed in the mid-1980's to provide real-time data access and modeling for the fire management organization. The IAMS required a considerable dedicated telecommunications network for data distribution. In an effort to reduce these inherent telecommunications costs, the BLM has moved into a "web server" environment. Many of the capabilities that were centrally located in the old IAMS have been moved to other web sites.

FIRE WEATHER WEBSITES

The principal Wildland Fire Management Information System (WFMIS) inputs remain the same with Remote Automatic Weather Station (RAWS) and National Lightning Detection Network (NLDN) information (Figure 3-DOI-2). BLM's new server system is called the BLM Wildland Fire Management Information Site (www.nifc.blm.gov). Additional fire management information is summarized and made available at the Desert Research Institute (wrcc.dri.edu and cefa.dri.edu) and the U.S. Forest Service Wildland Fire Assessment System (//svinet2.fs. fed.us/land/wfas/). Additionally, the BLM has utilized the Desert Research Institute's capabilities to respond quickly for website support.

AUTOMATED WEATHER STATIONS

The BLM's RAWS Program primarily collects meteorological data for fire weather forecasting. However, use of BLM's RAWS data set by other non-fire users has generated sufficient funding to permit year-round operation of the entire network. The BLM's Resource Management and Oregon O&C (West-Side) also operate RAWS networks which are much smaller and have specific program requirements that differ from fire management.

LIGHTNING DETECTION

In 1997, the BLM began contracting with a private vendor via the National Weather Service for lightning location data. Data are received at the NIFC in Boise, Idaho, and placed on the BLM WFMIS for qualified user access. Current plans are to continue the operation of the Alaska Automatic Light-

ning Detection System as an independent government-owed and operated system.

FIRE WEATHER SUPPORT

The BLM's Remote Sensing / Fire Weather Support Unit (RSFWSU) at NIFC provides the full range of program management, equipment dispatch, field and depot maintenance, support and data services for the BLM and numerous other government agencies. This interagency-staffed and funded facility performs work under long term agreements with those agencies within the government having similar equipment and requirements.

CLIMATE MONITORING

In addition to the meteorological monitoring BLM conducts primarily to support wildland fire management activities, the BLM also conducts site-specific climate monitoring at over 200 manual weather station locations on the public lands in the 11 western states and Alaska. The operation of these sites ranges from seasonal to annual, taking measurements of precipitation, temperature, soil moisture, and other meteorological parameters necessary to assess local climactic influences. These data are primarily used for natural resources management and planning at the local level.

PORTABLE WEATHER STATIONS

During the 1999 fire season, the Remote Sensing/Fire Weather Support Unit began a 2-year "proof of concept" effort with a portable weather station referred to as the Fire RAWS (FRWS). FRWS are intended for use on or near a fire line and can be rapidly relocated to points desired by Fire Behavior Analysts for real-time weather data. Due to the extreme fire season in both 1999 and 2000, the FRWS was used extensively and was found to be a valuable asset for firefighter safety and fire weather forecasting. Fire managers have also increased the use of FRWS to monitor intentionally-initiated prescribed burns.

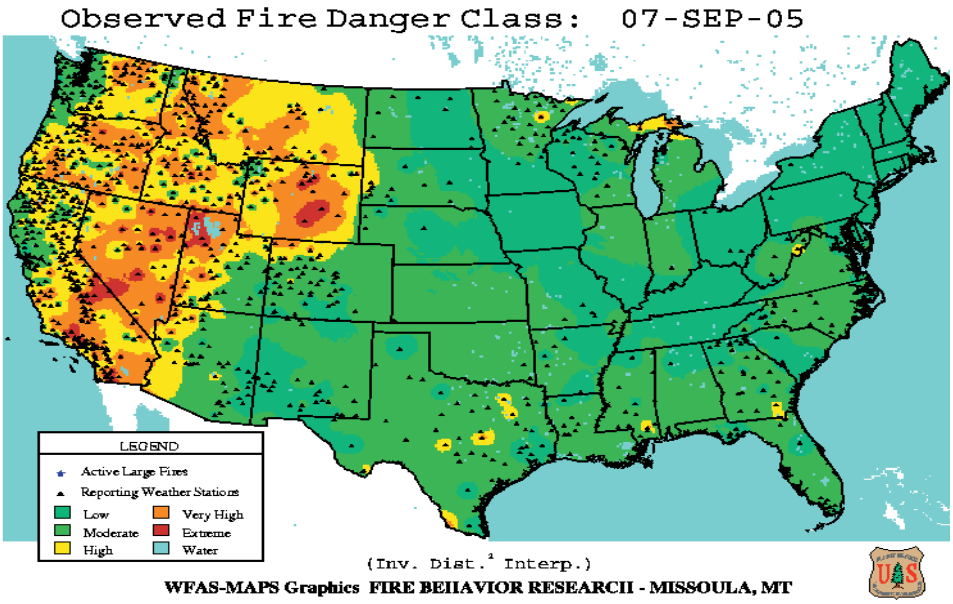


Figure 3-DOI-2. A National Interagency Coordination Center (NICC) graphic of Observed Fire Danger Class for the lower 48 states.

Currently, 42 FRWS systems are cached at NIFC for use during the 2006 season. FRWS collect, store, and forward data by interrogated voice radio with new data available every fifteen minutes. Satellite data can be retrieved from the BLM/NIFC website, and hourly satellite data is available to Fire Weather Forecasting Staff for spot forecasts and fire support from all central locations (Geographic Area Coordination Centers, NIFC, etc.).

ALL RISKS SUPPORT

After the terrorist attack on September 11th, 2001, the RSFWSU was tasked to provide near real-time meteorological data collection at the World Trade Center (Figure 3-DOI-3). This effort was in direct support of the Environmental Protection Agency's task of monitoring air quality in the vicinity of the collapsed towers. The unit also provided remote meteorological support for the Columbia Shuttle accident investigation and recovery effort, and RAWS support has generated interest from the Department of Homeland Security as it assesses its needs for remote and urban environmental monitoring. Using the personnel and resources available at the RSFWSU, the BLM can offer a rapid meteorological support capability that is unique across the Federal government.

BUREAU OF INDIAN AFFAIRS (BIA)

The Bureau of Indian Affairs collects atmospheric data to evaluate potentially irrigable Indian Trust lands in the Southwest. The Bureau also collects and shares fire weather data with other Federal agencies while participating in fire management activities for local and interagency use.

Currently, BIA operates the following instrumentation:

- 69 fire weather RAWS stations (permanent stations)
- 5 "manual" weather stations
- 13 portable RAWS stations used for Prescribed Fire
- 10 RAWS deployed on emergency stabilization projects.

MINERALS MANAGEMENT SERVICE (MMS)

The Minerals Management Service (MMS) gathers offshore meteorological data for use in the management of offshore oil and gas resources and sources of alternative energy. The data

Figure 3-DOI-3. Remote Sensing/Fire Weather Support Unit providing near-real-time meteorological data collection at the World Trade Center.

are used in air quality and oil-spill modeling, model development, and other research projects.

MMS operates a radar wind profiler (RWP) at the Louisiana Universities Marine Consortium (LUMCON) facility in Cocodrie, Louisiana (Figure 3-DOI-4). The profiler has been collecting data since October 2004 and will be operating over a three-year period. Data collected at this site may be accessed at http://weather.lumcon.edu/weather-data/doppler. The data will be applied to regional models for evaluating impacts from emission sources on ozone, fine particulate matter, and regional haze. The Service, in a cooperative agreement with The University of Houston (UH), is planning to support the installation and operation of an RWP at the UH Coastal Research Center (UHCRC) near Galveston, TX. The profiler is expected to be installed and operational in the summer of 2006 and will collect data for 3 years. In addition, MMS is providing funding for the operation of an RWP on a platform in the Gulf of Mexico in support of the Texas Air Quality Study-II (TexAQS-II) Field Study in 2006.

Another meteorological data collection effort is ongoing in the Beaufort Sea in Alaska, with six meteorological stations collecting data since 2001 (see http://www.resdat.com/mms/). Data collection will continue through FY 2006. The information will be applied to oil spill modeling and air quality impact evaluations.

MMS has a cooperative agreement with the Coastal Marine Institute (CMI) at Louisiana State University to study the relationships between visibility, haze, ozone, and PM2.5 and meteorological variables and to determine source regions for haze near the Breton National Wilderness Area in Louisiana. This study is expected to be completed in FY 2007.

The MMS is completing a study entitled The Breton National Wilderness Increment Analysis. This study consists of a meteorological and air quality modeling analysis in and around the Breton National Wilderness Area (NWA), which is a Clean Air Act Prevention of Significant Deterioration (PSD) Class I area located on a chain of barrier islands off southeastern Louisiana. The objective of the study is to assess the impacts of Outer Continental Shelf (OCS) oil and gas production activities on the PSD increment consumption. (PSD increment consumption is the maximum level of pollutant increase allowed over a baseline concentration.) This effort is expected to be completed by the end of FY 2006. Copies of final reports in past meteorological and air quality studies in the Gulf of Mexico may be found at http://www.gomr.mms.gov/homepg/regulate/environ/techsumm/rec_pubs.html.

NATIONAL PARK SERVICE (NPS) AND FISH AND WILDLIFE SERVICE (FWS)

The National Park Service monitors air quality and visibility in a number of national parks and monuments. Gaseous pollutant data are collected on continuous and integrated (24-hour to weekly) bases. Surface meteorological data are collected and analyzed for hourly averages. Precipitation chemistry is determined on week-long integrated rainfall samples. Twenty-four-hour-average particle concentrations (mass, elemental analyses, some chem-

Figure 3-DOI-4. The MMS Profiler at LUMCON facility in Cocodrie, Louisiana.

ical constituent analyses) are measured every third day. Atmospheric light extinction is measured continuously and relayed to a central location for analyses.

MODELING

The NPS also conducts and contracts research to develop and test air quality models to assess long-range transport, chemical transformation, and deposition of air pollutants. These models are used to estimate source contributions to, and to identify source regions responsible for, observed pollutant loadings.

JOINT MONITORING AND RESEARCH

The Fish and Wildlife Service Air Quality Branch and the NPS Air Resources Division operate under an interagency agreement and are collocated in Lakewood, Colorado. Expertise from both agencies is pooled to address the air quality issues that are the responsibility of the Assistant Secretary of the Interior for Fish and Wildlife and Parks.

The NPS oversees the operation of the Interagency Monitoring of Protected Visual Environments (IMPROVE) network and the IMPROVE Protocol network in cooperation with the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the United States Forest Service (USFS), the FWS, the BLM, and various State organizations. Currently, the network has about 170 sites, mostly funded by the EPA in support of their regional haze regulations and through other cooperators. The enhanced network allows a better characterization of visibility and fine particle concentrations throughout rural and remote areas of the country (Figure 3-DOI-5).

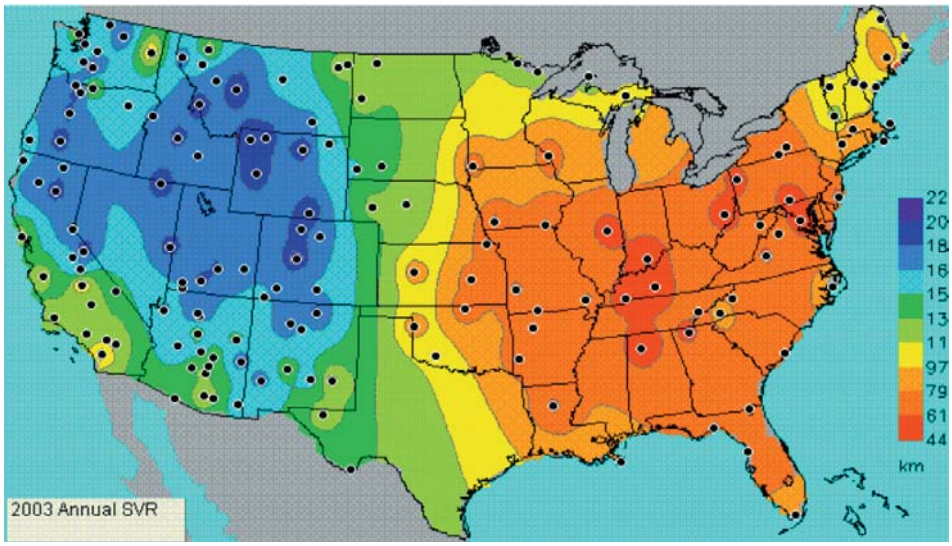


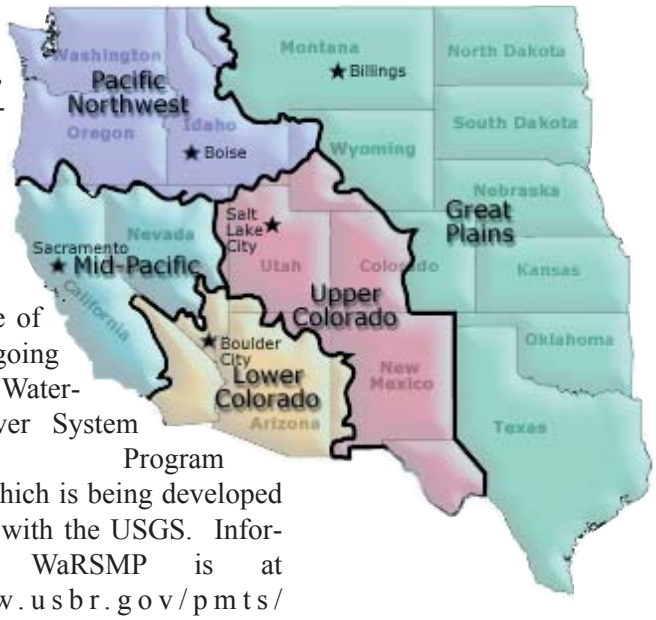
Figure 3-DOI-5. Map of annual average standard visual range (SVR), in kilometers, calculated from IMPROVE particle concentrations. Also shown are the locations of most of the IMPROVE and IMPROVE protocol sites during 2003 (http://vista.circa.colostate.edu/views).

BUREAU OF RECLAMATION

The Bureau of Reclamation (Reclamation) activities requiring the collection and use of meteorological data include water supply forecasting, snowpack water equivalent assessment, river system management, reservoir operations, irrigation scheduling, drought status assessment, flood hydrology, and projects related to hydroelectric energy resources.

One example of such an ongoing activity is the Watershed and River System Management Program (WaRSMP), which is being developed in partnership with the USGS. Information on WaRSMP is at http://www.usbr.gov/pmts/rivers/rsmgwtrmg.htm.

Other key players in this effort include TVA, the Corps of Engineers, NOAA, NASA, NRCS, the University of Colorado and Colorado State University. This program provides a data-centered framework for science-based water resources decision making.



Major components are:

- Hydrologic Database (HDB),
- Modular Modeling System (MMS),
- RiverWare river system modeling framework,
- Stochastic Analysis, Modeling and Simulation (SAMS) system,
- Agricultural WAter Resources Decision Support (AWARDS) and
- Evapotranspiration Toolbox (ET Toolbox) system.

HYDROLOGIC MODELING

The SAMS hydrologic modeling system is being used in WaRSMP to assist water resource managers in developing likely hydrologic scenarios for water supplies. It allows users to test various water resources management strategies, including extreme drought and high-flow scenarios which haven't been encountered in the historical period of record.

The RiverWare and HDB data-centered decision support system enables water managers to examine a variety of observed and forecast hydrologic scenarios using hourly, daily, or monthly data within the legal and physical constraints on operations of the river system. This model provides a holistic management tool for watershed and river systems, in order to meet a variety of competing demands for water.

Each new river system requires considerable development work (2-3 years) for RiverWare and HDB implementation. However, such a system can provide for efficient water operations management, and is especially useful during periods of drought and surplus - as demonstrated by the recent "Colorado River Interim Surplus Criteria: Final Environmental Impact Statement".

Current Reclamation projects under WaRSMP include:

- Planning and developing HDB, MMS and RiverWare systems for the Gunnison, San Juan, Rio Grande, Yakima, and Truckee river systems.
- Development of expanded capabilities to allow HDB to function as the Database of Record which will document management decisions and the data used to make them for Reclamation's Upper and Lower Colorado regions as well as other participating offices.
- SAMS integration and testing for the lower Colorado and Truckee River Basins.
- Implementing AWARDS systems to improve the efficiency of water management and irrigation scheduling for the Tualatin Project, Upper Columbia project areas, and Lower Colorado area.
- Developing the AWARDS/ET Toolbox system in the Middle Rio Grande and providing 24-hour water use estimates for input, via the Corps of Engineers' Hydrologic Engineering Center Decision Support System or a new HDB, to the Rio Grande RiverWare.
- Implementing similar AWARDS/ET Toolbox systems with input to local HDBs and RiverWare systems in the Upper Columbia, Lower Colorado, and possibly the Truckee-Carson areas.
- Integration and testing of emerging Land Surface Modeling Products from NASA's Global Land Data Assimilation Systems for snow mapping, surface energy and water budgets and ET analysis and prediction for water operations management.
- Testing and development of weather and climate products from the Global Energy and Water Cycle Experiment (GEWEX) for water supply and demand forecasting.

INSTRUMENTATION AND DATA ACQUISITION

NEXRAD estimates of precipitation are used for water supply and water delivery decision-making. Water managers can view the distribution of precipitation over watersheds that supply water to storage facilities, and examine the detailed spatial distributions of precipitation over the irrigated areas along with estimates of soil moisture, and evapotranspiration from crops and riparian vegetation.

The Watershed and River Systems Management Program focuses on integrating multi-disciplinary science into decision support systems that enable water managers to make the best deliveries of water to stakeholders.

Currently, Reclamation's HYDROMET system collects data from approximately 400 hydrometeorological data collection platforms (DCPs) which transmit data in real-time through GOES to Reclamation's DRGS in Boise, Idaho. AGRIMET is another network of 60 DCPs dedicated to analysis of crop water use and water conservation in the Pacific Northwest.

Data collected and products created in Boise are electronically transferred to other BLM, Federal and state offices. Reclamation's primary real-time hydrometeorological information from the NWS, USGS, NASA, and other agencies is displayed on the AWARDS / NEXRAD / ET Toolbox web site: http://www.usbr.gov/pmts/rivers/awards/index.html.

Water supply information from cumulative precipitation estimates from radar is also provided in areas where snowfall is an important source of water. Links directly to USDA Natural Resources Conservation Service and NOAA/National Centers for Environmental Prediction analysis and forecasting web sites are provided to further document the latest information.

TECHNICAL INFORMATION

The National Xeriscape Demonstration Program (NXDP) is nearing an end. The NXDP was initiated by Reclamation to estimate the benefits of water conserving landscaping. In partnerships with States, field demonstration projects were conducted in Fargo

ND, Austin TX, the Colorado Front Range, Phoenix AZ, and southern Nevada. Water savings ranged from 18 to over 50 percent in the demonstration projects, strongly suggesting water planners should consider this water conservation alternative as a supply development option.

SNOWPACK ASSESSMENT

Snowmelt represents about 80 percent of reservoir storage in Colorado and is largely responsible for spring flooding events in the state. Therefore it is highly desirable to know snowpack characteristics, such as its snow water equivalent (SWE), its spatial and elevation distribution, and its evolution with time during the water year. With support of the Colorado Water Conservation Board (CWCB), Reclamation has adapted the Snow Data Assimilation System (SNODAS) for enhanced snowpack assessment in the state of Colorado. The SNODAS was developed by the National Operational Hydrologic Remote Sensing Center (NOHRSC), a National Weather Service unit, and data are acquired through the National Snow and Ice Data Center.

SNODAS consists of a spatially distributed snow energy and mass balance model, coupled with an assimilation of all available SWE, snow depth, and snow cover data (from surface, aircraft, radar, satellite). Model outputs are at 1 km resolution and include SWE, snow depth, snowmelt, pack temperature, and sublimation. Comparison with data from Snow Telemetry (SNOTEL) sites and satellite imagery shows faithful representation of SWE and snow cover, respectively. Basin average SWE is substantially reduced over that of SNOTEL because the former is a basin-wide spatial average instead of an arithmetic average of a few high-elevation points. This difference is important hydrologically and holds the promise of coupling snowmelt with a hydrologic model to produce streamflow hydrographs. Such hydrographs would be extremely useful to the decision support systems of water management agencies such as the CWCB and Reclamation, with the ultimate aim of improved forecasting of water supplies and flooding. Colorado SNODAS products have been posted daily at http://www.usbr.gov/pmts/rivers/awards/SNODAS/SNODAS_CO_hist.html since October 2003. Future work will consist of verification of SNODAS outputs, improvement of precipitation inputs, and coupling to a hydrologic model. An example of such an online product is given by Figure 3-DOI-6 (see the next page).

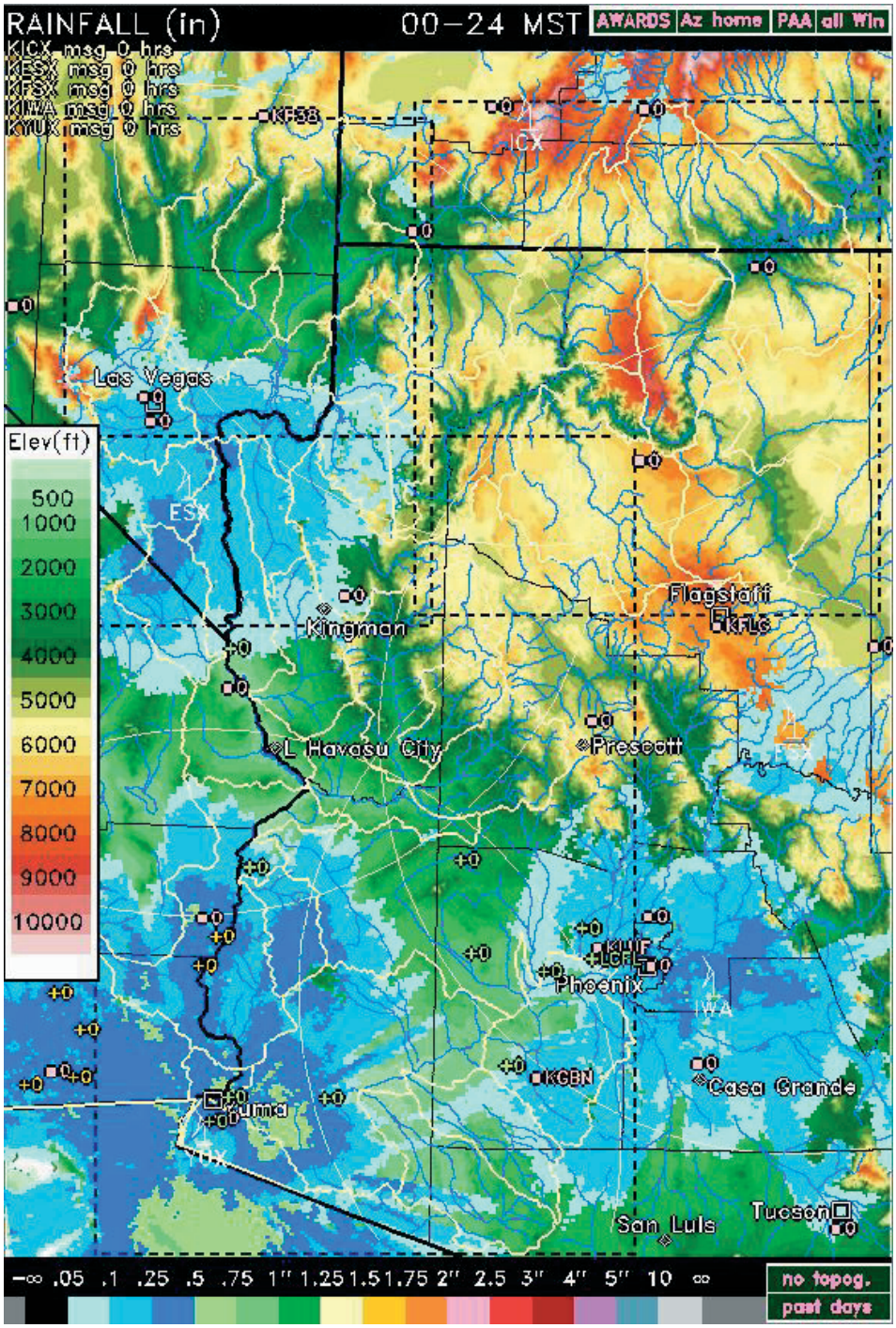


Figure 3-DOI-6. Agricultural Water Resources Decision-Support (AWARDS)/ET Toolbox example for the Lower Colorado River basin. AWARDS merges the precipitation accumulation algorithm (PAA) estimates from five WSR-88D (or NEXRAD) radars into a 2x2km grid.

DEPARTMENT OF STATE CLIMATE AND ATMOSPHERIC PROGRAMS

The Department of State (DOS) plays an active role in international climate/meteorological policy making as a result of the growing worldwide concern with global environmental issues, including the depletion of the stratospheric ozone layer and climate change. The role of DOS has principally revolved around preparation and negotiation of the United States position in three fora: (1) the Conference of the Parties to the Vienna Convention and its Montreal Protocol on Substances that Deplete the Ozone Layer, (2) the Intergovernmental Panel on Climate Change (IPCC); and (3) negotiation under the United Nations Framework Convention on Climate Change (FCCC). In addition, over the past few years the DOS has played a central and active role in the development and implementation of a number of international science and technology initiatives including the Group on Earth Observations, the Carbon Sequestration Leadership Forum, the International Partnership for the Hydrogen Economy, the Methane-to-Markets Partnership, and Generation IV (a U.S.-led program working on new fission reactor designs that will be safer, more economical and secure).

Stratospheric ozone depletion has been recognized as a critical health and environmental problem for more than a decade. Under DOS leadership, the U.S. worked to negotiate international agreements to phase out ozone-depleting substances, which should lead to a recovery of the ozone layer in the next century. To date, these treaties have been signed and ratified by more than 170 countries (including the U.S.). These countries represent 99 percent of the world's production of ozone depleting substances.

The Intergovernmental Panel on Climate Change (IPCC), which was established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), held its first session in 1988. This organization serves as a government forum to assess scientific, technical and socioeconomic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.. In doing so, the Panel draws on the expertise of thousands of scientists and technical experts. The IPCC is currently organized into three working groups, which examine (1) the state of the science, (2) impacts and adaptation, and (3) mitigation. The IPCC released its first and second assessment reports in 1990 and 1995, respectively, and a third assessment report from each of the working groups was published in 2001. The fourth assessment report, due in 2007, is currently under preparation. In addition to preparing assessment reports, the IPCC also contributes to international negotiations through preparation and review of special reports and development of methodologies requested by the Framework Convention on Climate Change (FCCC).

The FCCC was negotiated beginning in February 1991; the Convention was open for signature in Rio de Janeiro at the Earth Summit in June 1992. As of May 2004, it had been ratified by 189 countries, including the U.S. The ultimate objective of the Convention is to stabilize greenhouse gas emissions at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system. It states that such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner. The Convention calls for all countries to develop inventories of their emissions and sinks of greenhouse gases and calls upon developed countries and economies in transition to aim to return these emissions to their 1990 levels by the year 2000.

In December 1997, parties to the Convention adopted the Kyoto Protocol, which commits developed countries to reducing their collective emissions of greenhouse gases by at least 5 percent by the period 2008-2012. Following Russian ratification in late 2004, the Kyoto Protocol entered into force in February 2005. In early 2001, the U.S. announced that it would not ratify the Kyoto Protocol. The U.S. approach to addressing the challenge of climate change harnesses the power of markets and technological innovation. It also holds the promise of a new partnership with the developing world and it recognizes that climate change is a complex, long-term challenge that will require a sustained effort over many generations.

Today the U.S. is actively engaged in addressing climate change through the Convention, through a wide range of international science and technology initiatives, through multilateral efforts such as the Asia-Pacific Partnership for Clean Development and Climate and bilateral partnerships with 14 countries including Australia, Brazil, Canada, China, India, Italy, Japan, and other countries. Together these initiatives will help improve our global capability to understand and address issues associated with climate change in a manner that supports broader sustainable development goals.

In addition to its primary role in the fora listed above, DOS is active in several relevant interagency processes, including the Committee on Environment and Natural Resources (CENR) of the National Science and Technology Council and the Interagency Working Group on Climate Change Science and Technology (IWGCCST). The CENR was established in 1993 to coordinate scientific domestic programs. Created in 2002, the IWGCCST is a sub-Cabinet level group that reviews all programs that contribute to climate change science and technology. Furthermore, while the emphasis on global environmental issues is a key new component of the department's focus, traditional DOS responsibilities, described in earlier Federal plans, continue. These include, but are not limited to, international aspects of food policy, disaster warnings and assistance, WMO and UNEP activities, and international meteorological programs.

ENVIRONMENTAL PROTECTION AGENCY WEATHER PROGRAMS

Environmental Protection Agency (EPA) is responsible for working with state, local, and other Federal government agencies to provide user-appropriate and scientifically-credible air quality and meteorological programs to support regulatory applications. Applied research and meteorological support are furnished primarily by EPA's National Exposure Research Laboratory and EPA's Office of Air Quality Planning and Standards, both located in Research Triangle Park, North Carolina. This activity is provided through interagency agreements with the National Oceanic and Atmospheric Administration (NOAA), which assigns approximately 50 research meteorologists to the EPA.

Meteorological support to EPA's Office of Research and Development, EPA's Office of Air and Radiation, EPA Regional Offices, and to state and local agencies includes:

- Development and application of air quality models for pollution control, direct and indirect exposure assessments, and emission control strategy assessment;
- Preparation and performance of dispersion studies and air quality model evaluations;
- Review of meteorological aspects of environmental impact statements, state implementation plans, and pollution variance requests;
- Air quality forecasting; and
- Emergency response planning in support of homeland security.

Meteorological expertise and guidance are also provided for the national air quality standards, modeling guideline, and policy development activities of the EPA.

In light of the 1990 Amendments to the Clean Air Act and the recent national rules, air quality models and the manner in which they are used are expected to continue to grow over the next few years. In the area of pollutant deposition, the evaluation of nitrogen, oxidant, sulfur and aerosol chemistries will help to clarify the roles of model formulation, cloud processes, aerosols, radiative transfer, and air/surface exchanges in air quality model predictions, leading to a better understanding of model predictions relative to control strategy assessments. Further development and evaluation of existing air quality models will take place to accommodate the inter-pollutant effects resulting from the variety of control programs that are now or may be in place, such as the new National Ambient Air Quality Standards for ozone and particulate pollution. These inter-pollutant effects include trade-offs among controls on ozone, sulfur oxides, nitrogen oxides, and volatile organic compounds, as well as developing predictable methods of forecasting the impacts on various measures of air quality.

With respect to the fine particulate model development, air quality models are being enhanced to accurately predict aerosol growth from precursors over local and regional transport distances. To assist in the evaluation of the contribution of various sources to regional air degradation, inert tracer and tagged species numerical models have been developed. These models will introduce separate calculations for inert or reactive chemical species emitted from a particular source or region. The calculations will proceed to simulate transport and transformation to a receptor point, where the contribution of emission sources can be discerned.

Atmospheric research is the area of the effects of climate change on regional air quality involves both analytical and statistical climatology as well as support for regional-scale climate model development.

Research in human exposure modeling includes micro-environmental monitoring and modeling, and development of exposure assessment tools. Micro-environmental algorithms are being developed based on field data to predict air quality in buildings, attached garages, and street canyons. These improved algorithms are then incorporated into micro-environmental simulation models for conducting human exposure assessments within enclosed spaces in which specific human activities occur.

In addition to the above major areas, dispersion models for inert, reactive and toxic pollutants are under development and evaluation on all temporal and spatial scales, e.g., indoor, urban, complex terrain, mesoscale, regional, and global. Other efforts include modeling nutrient deposition to Chesapeake Bay and mercury deposition to the Florida Everglades; and determination of meteorological effects on air quality. Atmospheric flow and dispersion experimental data obtained from wind tunnel and convection tank experiments in the EPA Fluid Modeling Facility will be used to continue development and evaluation of these models along with providing researchers with insight into the basic physical processes that affect pollutant dispersion around natural and man-made obstacles. For example, the transport and dispersion of airborne agents in the Manhattan, New York area were simulated in the wind tunnel to evaluate Computational Fluid Dynamics modeling systems in an effort to help build confidence in mod-

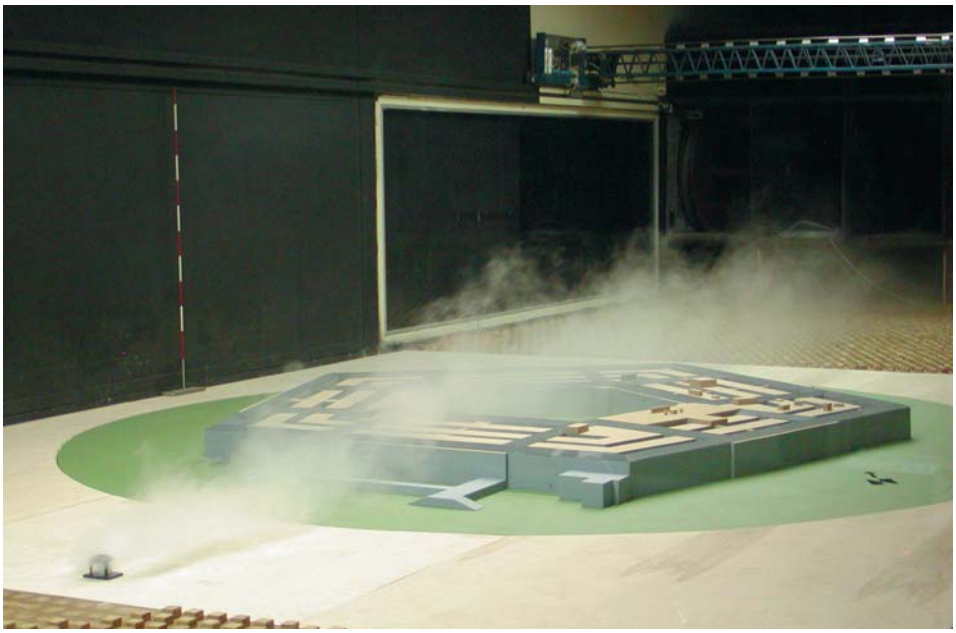


Figure 3-EPA-1. Model of the Pentagon used in the wind tunnel of the Fluid Modeling Facility to study the transport and dispersion of airborne agents.

eling assessment source-receptor relationships for horrific events such as the one that occurred on September 11, 2001 A similar study was conducted for the Pentagon (Figure 3-EPA-1) and will be conducted for the Washington, DC area.

Over the past twenty-five years, numerous air quality simulation models have been developed to estimate reductions in ambient air pollutant concentrations resulting from potential emission control strategies. Separate models were developed, for example, for tropospheric ozone and photochemical smog, for acid deposition, and for fine particles. Distinct models also existed for addressing urban scale problems and the larger regional scale problems. It has been recognized, however, that the various pollutant regimes are closely linked chemically, spatially/temporally in the atmosphere. The principal purpose of the Community Multi-scale Air Quality (CMAQ) modeling project was to develop a "one atmosphere" flexible environmental modeling tool that integrates the major atmospheric pollution regimes in a multi-scale, multi-pollutant modeling system. This system will enable high-level computational access to both scientific and air quality management users for socio-economic applications in community health assessments and ecosystem sustainability studies.

After seven years of development, the Models-3/CMAQ was first released in June 1998, and is being updated annually for use by Federal and state agencies, industry, and academia. The latest version of CMAQ, which includes science enhancements and computational efficiencies, will be released in September 2006. It is also intended to serve as a community framework for continual advancement and use of environmental assessment tools. CMAQ, configured for the Windows-NT computer system, is available on tapes from the National Technical Information Service (NTIS). It is accompanied by an Installation and Operations Manual, a User Manual, a Science Document, and a tutorial providing step by step instructions for use of the modeling capabilities. Additional information is available at the Models-3 web site at http://www.epa.gov/asmdnerl/models3/. Figure 3-EPA-2 illustrates the results of CMAQ for ozone and fine particulate matter (PM2.5), sulfates, and visibility for August 8, 2001, for the contiguous U.S. at 36-km horizontal grid dimension, a period of widespread ambient pollution in the nation.

In FY 2005, EPA worked closely with the National Center for Environmental Prediction of the National Weather Service (NWS) in the continued development, evaluation, and use of a coupled meteorological-chemical transport model (WRF-CMAQ) for predicting ambient air quality over the Continental U.S.. This capability is built on years of research in air quality, exemplified by the NOAA-led New England Pilot Air Quality Study in 2002 and 2004. In the first phase of the forecasting project, NWS implemented the Eta-CMAQ modeling system, to provide daily forecast guidance for ozone for the northeastern U.S. starting from September 2004. Within the next few years, the system for ozone will deploy nationwide. Within ten years, the operational forecast capability is projected to be able to forecast particulate matter. State and local air quality management agencies will continue to forecast local air quality, assisted in their efforts by the addition of national forecast guidance for the concentrations of ozone and other air pollutants.

EPA participation in the interagency Information Technology Research and Development (IT R&D) Program is developing a modeling framework that supports integration of diverse models (e.g, atmospheric, land surface, and watershed) as part of EPA's Multimedia Integrated Modeling System (MIMS) project, described at http://www.epa.gov/asmdnerl/mims/. EPA's IT R&D work also enables increased efficiency in air quality meteorological modeling through research on parallel implementation of the CMAQ modeling system. The evolving MIMS research seeks to improve the environmental manage-

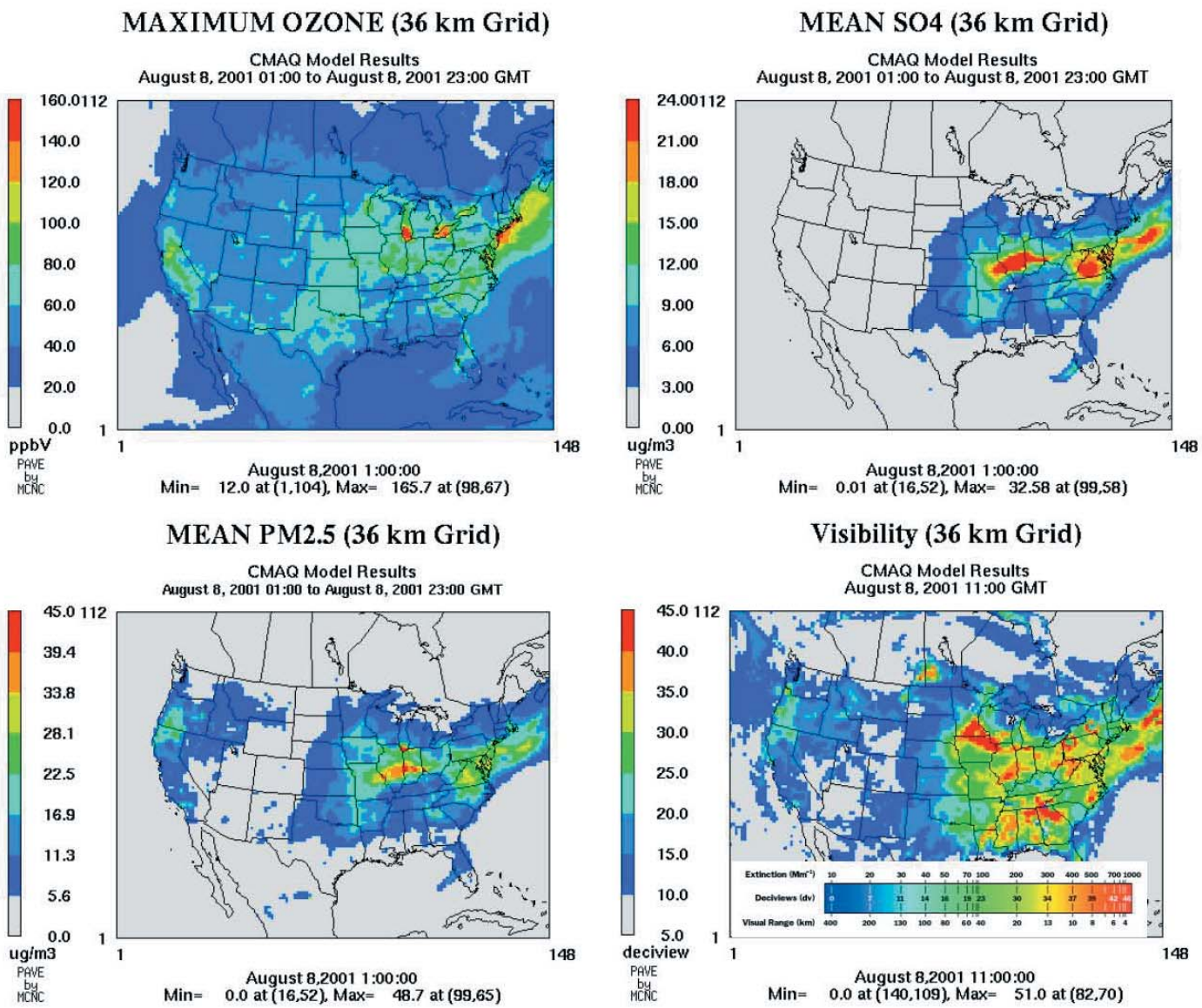


Figure 3-EPA-2. CMAQ simulation results for August 8, 2001, for the contiguous U.S. at 36-km horizontal grid spacing showing: (upper left) maximum 1-hour average ozone concentrations (ppbV) in each grid cell; (upper right) 24-hour averages of sulfate concentrations (micrograms/m3); (lower left) 24-hour averages of PM2.5 concentrations (micrograms/m3) in each 36-km grid cell; and (lower right) visibility (deciview - see insert) in each grid cell.

ment community's ability to evaluate the impact of air quality and watershed management practices, at multiple scales, on stream and estuarine conditions. Toward this goal the primary objectives include:

• Developing a prototype multiscale integrated modeling system with predictive meteorological capability for transport and fate of nutrients and chemical stressors;

• Enabling the use of remotely sensed meteorological data; and

3. developing a computer-based problem solving environment with ready access to data, models, and integrated visualization and analysis tools for water and air quality management, local and regional development planning, and exposure-risk assessments. Under the MIMS project, a variety of research areas are being pursued such as the integration of the National Weather Service Next Generation Radar (NEXRAD) Stage IV data into watershed modeling applications; enhanced atmospheric dry deposition models; multi-scale, spatially explicit watershed modeling tools; and model-coupling technology for integrating media specific models. The MIMS development extends the open architecture approach demonstrated in the third generation modeling system, CMAQ, and is the next generation of modeling frameworks under the IT R&D program.

EPA also maintains relations with foreign countries to facilitate exchange

of research meteorologists and research results pertaining to meteorological aspects of air pollution. For example, agreements are currently in place with Canada, Greece, Japan, Korea, China, India, and Mexico, and with several European countries under the NATO Committee on the Challenges of Modern Society (CCMS).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WEATHER PROGRAMS

The National Aeronautics and Space Administration (NASA) Headquarters Weather Support Office has continued to improve NASA's weather support capabilities for both manned and unmanned space launch vehicles. It is expected that these improvements will strengthen and enhance the information provided to the ground-based decision makers and astronaut observers to insure that NASA achieves the best operational posture for Space Shuttle launches and landings. The goal of the operations program is to provide the specialized meteorological data needed by operational forecasters at the Kennedy Space Center (KSC) and Johnson Space Center (JSC). NASA also maintains a sophisticated fleet of eighteen Earth-monitoring satellites, measuring a vast number of Earth properties. The focus of Earth Science Research is to integrate satellite observations, numerical model and theoretical studies of various Earth system attributes. These attributes include ocean currents, temperature and biological activity; atmospheric ozone and aerosols; tropical rainfall, lightning; atmospheric temperature and humidity structure; Antarctic and Arctic sea ice; volcanic emissions and gravitational anomalies in the Earth's crust. NASA also performs aviation research to improve safety, develop weather information technologies, and increase aviation system capacity. Advanced operations technologies can increase the number of operations per runway in all weather conditions. The research applies to both commercial and general aviation.

OPERATIONS

The goal of the National Aeronautics and Space Administration (NASA) weather operations program is to provide specialized meteorological data and techniques needed by Air Force forecasters at Cape Canaveral Air Force Station (CCAFS), adjacent to Kennedy Space Center (KSC), and by the NWS' Spaceflight Meteorology Group (SMG) at Johnson Space Center (JSC), to support NASA's Space Shuttle and Expendable Launch Vehicle (ELV) programs. Their greatest challenge is to accurately measure and forecast the mesoscale weather events that strongly impact ground processing, launch, and landing operations.

To successfully support the diverse, unique and complex requirements of their many customers' 24/7 operations, in the mesoscale driven lightning capital of America, requires:

- A sophisticated weather infrastructure which includes systems normally found only in research field programs rather than operations;
- A dedicated capability to transition research and technology to support new or poorly satisfied operational requirements;
- Rigorous training to ensure the weather infrastructure, diverse customer requirements, and dynamic, mesoscale weather are thoroughly understood; and
- At least 2-3 years of on-site experience to adequately master the infrastructure, the weather, and the requirements sufficiently to provide timely, tailored, accurate support to the many weather sensitive daily operations.

The focal point for satisfying requirement 3 above and assisting with requirements 1 and 2 above is the Applied Meteorology Unit (AMU). The AMU, co-located with the Air Force's Range Weather Operations at CCAFS, develops, evaluates and, if warranted, transitions new meteorological technology into operations.

For instance, the AMU strives to develop techniques and systems to help predict and avoid the impacts of Central Florida's frequent thunderstorms which endanger the ground processing, launch, and landing operations of the American Space Program-Space Shuttle, DOD, and commercial interests. The AMU has focused special attention on evaluating and transitioning mesoscale numerical models, and developing forecast techniques applicable to Central Florida. The AMU functions under a joint NASA, Air Force, and NWS Memorandum of Understanding.

Current AMU tasks include:

- Task: Objective Lightning Probability Forecast: Phase I.

Goal: Develop a set of statistical equations to forecast the probability of

lightning occurrence for the day. This will aid forecasters in evaluating flight rules and determining the probability of launch commit criteria violations, as well as preparing forecasts for ground operations.

• Task: Severe Weather Forecast Decision Aid.

Goal: Create a new forecast aid to improve the severe weather watches and warnings meant for the protection of KSC and CCAFS personnel and property.

• Task: Shuttle Ascent Camera Cloud Obstruction Forecast.

Goal: Develop a model to forecast the probability that at least three Shuttle ascent imaging cameras can view the Shuttle launch vehicle (LV) unobstructed by cloud at any time from launch to Solid Rocket Booster (SRB) separation.

• Task: Stable Low Cloud Evaluation.

Goal: Examine archived data collected during rapid stable cloud development events resulting in cloud ceilings below 8000 ft at the Shuttle Landing Facility (SLF). Document the atmospheric conditions favoring this type of cloud development to improve the ceiling forecast issued by the Spaceflight Meteorology Group (SMG) for Shuttle landings at KSC.

• Task: Hail Index.

Goal: Evaluate current techniques used by the 45 Weather Squadron (45 WS) to forecast the probability of hail occurrence and size. Hail forecasts are required to protect personnel and material assets at KSC, CCAFS, Patrick Air Force Base and the Melbourne International Airport. The evaluation results will be used by the 45 WS to determine if a new technique is needed.

• Task: RSA and Legacy Wind Sensor Evaluation.

Goal: Compare wind speed and direction statistics from the legacy and RSA sensors on the Eastern (ER) and Western (WR) Ranges to determine the impact of the sensor changes on wind measurements. The 45 WS and 30 WS at Edwards AFB, CA, need to know of any differences in the measurements between the two systems as they use these winds to issue weather advisories for operations.

• Task: Volume Averaged Height Integrated Radar Reflectivity (VAHIRR).

Goal: Transition the VAHIRR algorithm into operations. The current lightning launch commit criteria (LLCC) for anvil clouds to avoid triggered lightning are overly conservative and lead to costly launch delays and scrubs. The VAHIRR algorithm was developed as a result of the Airborne Field Mill program to evaluate a new LLCC for anvil clouds. This algorithm will assist forecasters in providing fewer missed launch opportunities with no loss of safety compared with the current LLCC.

• Task: Mesoscale Model Phenomenological Verification Evaluation.

Goal: Find model weather-phenomena verification tools in the literature that could be transitioned into operations. Forecasters use models to aid in forecasting weather phenomena important to launch, landing, and daily ground operations. Methods that verify model performance are needed to help forecasters determine the model skill in predicting certain phenomena.

• Task: Advanced Regional Prediction System (ARPS) Optimization and Training Extension.

Goal: Provide assistance and support for upgrading and improving the operational ARPS and ARPS Data Analysis System (ADAS) that is used to make operational forecasts at the National Weather Service in Melbourne, FL (NWS MLB) and SMG forecast offices.

• Task: User Control Interface for ADAS Data Ingest.

Goal: Develop a GUI to help forecasters at NWS MLB and SMG manage the data sets assimilated into the operational ADAS.

• Task: Anvil Transparency Relationship to Radar Reflectivity.

Goal: Determine if the NWS MLB WSR-88D radar can be used to analyze anvil cloud transparency

• Task: Range Standardization and Automation (RSA) Support.

Goal: Help ER management evaluate proposed designs and implementations of the weather systems upgrade by the RSA and SLRSC contractors.

Additionally the KSC Weather Office continues to work with the ER to improve the KSC and ER weather infrastructure and improve operational processes and facilities in the following areas:

• Lightning Launch Commit Criteria (LLCC) [Airborne Field Mill (ABFM)] Program.

The Weather Office continued to direct the analysis of data gathering from KSC's major field research program called the Lightning Launch Commit Criteria (LLCC) program. The LLCC program used an aircraft equipped with field mills and cloud physics sensors, in combination with several ground based radars and other sensors, to collect the data necessary to relax the lightning launch constraints while making them even safer. LLCC was cooperatively funded by the Shuttle program, NASA ELVs and the USAF. The team included more than 50 personnel from eleven organizations including other Governmental agencies, NASA Centers, universities and their contractors.

Based on analyses of the extensive data base of in-situ and radar measurements, the team developed revised LLCC for both Attached Anvils and Detached Anvils. Working with colleagues from the National Center for Atmospheric Research (NCAR), Marshall Spaceflight Center (MSFC), the University of Arizona (U AZ), the Hurricane Research Division (NOAA/HRD), National Severe Storms Lab., Aerospace Corp. and oth-

ers, KSC developed and applied software to perform a variety of analyses on the massive data set. These analyses included correlation and power spectral analyses, and extensive statistical examinations of the radar, cloud physics and electric field data.

KSC facilitated and participated in defining the new LLCC. To help the Lightning Advisory Panel (LAP) determine the threshold electric field aloft that poses a triggered lightning hazard, KSC acquired information from Shuttle and Titan about the length of the ionized plum from their solid rocket motors. From data obtained elsewhere on the likely potential difference required to trigger lightning, the LAP used the plume lengths to convert the triggering threat potential to a corresponding threshold electric field.

In order to automate processing of ABFM data for the determination of the decay of electric fields with distance from cloud edges, KSC developed an automated cloud edge detection algorithm. A paper describing the algorithm and its testing appeared in the May 2004 issue of the Journal of Atmospheric and Oceanic Technology. (Ward, J.G. and F.J. Merceret, 2004: *An Automated Cloud-Edge Detection Algorithm Using Cloud Physics and Radar Data,* J. Atm. & Ocean. Tech., 21(5), 762-765)

• Winds.

The KSC Weather Office (KSCWO) requested the Shuttle Program to reexamine its day of launch upper air winds procedures to ensure spatial and temporal variability are being optimally accounted for. The KSCWO presented several briefings on temporal wind persistence as a function of vertical feature size and related instrumentation matters to the Space Shuttle Natural Environments Panel challenging engineers from the Shuttle, Titan and new Expendable Launch Vehicle programs (Atlas V and Delta IV) to reconsider their assumptions and launch day procedures.

• Visibility Sensors.

In FY 2004, KSC began transmitting Visibility and Soil Moisture data to JSC/SMG from five suites of newly installed sensors west of KSC to aid in the forecast of morning fog that could impact Shuttle landings.

• Range Standardization and Automation (RSA).

The KSC Weather Office, SMG at JSC, and the AMU continue to actively participate in plans and proposals for projects managed by the RSA program. RSA is a major Air Force program to modernize the Eastern and Western Range infrastructure. Many issues remain with RSA's pending changes. Thus the Air Force and NASA weather communities continued to expend significant resources to solve potential major RSA deficiencies, since NASA KSC, JSC and MSFC depend heavily on this infrastructure for their weather support. A major success was the RSA contractor's decision to discard their proposed Control and Display (C&D) system, and instead partner with NOAA's Forecast Systems Lab to deliver a COTS AWIPS (Automated Weather Information System). This will provide Range Weather Operations with a very capable system that is cost effective, and compatible with both future AWIPS upgrades and with SMG. However, in FY 2003 and FY 2004, the Air Force budget redirection seriously threatened cancellation of the entire RSA weather system which would have seriously degraded long term weather support to the American Space Program. Fortunately, the program is still progressing. Although deliveries of some weather sensors, models, and control and display systems began in FY 2000, budget restrictions have delayed full operational capability and acceptance by the Eastern Range to FY 2007 (a decade plus delay from original schedule).

• Spacelift Range Systems Contract (SLRS-C).

In addition to the RSA Modernization programs, the new SLRS-C provides Sustaining Engineering for the legacy systems and also the systems RSA is delivering. SLRS-C is currently upgrading or replacing three systems currently owned by NASA Kennedy Space Center: the 50 MHz Doppler Radar Wind Profiler; the Shuttle Landing Facility Weather Tower and Sensor system; and the Lightning Detection and Ranging (4D total lightning) system. Upon completion of each program, the system will be turned over from NASA/KSC to the Eastern Range. Despite numerous logistical and programmatic hurdles all three programs will likely move forward to completion: SLF in FY 2006, 4D lightning in FY 2007, and 50 MHz profiler in FY 2007.

• 50 MHz Doppler Radar Wind Profiler (DRWP).

Replacement of the KSC DRWP and its electronic components began in FY 2004 and finished in FY 2005. Meanwhile, several antenna field issues were corrected. The Air Force funded a project to improve the drainage of the DRWP antenna field that flooded during very heavy rains. During droughts, the very dry antenna ground plane caused erroneous side lobe returns. The Profiler O&M contractor designed and a contractor installed a sprinkler system to wet the antenna field during droughts. The sprinkler system is now installed which solved the side-lobe problem during dry weather.

• Shuttle Landing Facility (SLF) Weather Sensors.

LRSC also contracted to replace and modernize all SLF weather instrumentation. SLRS-C chose the AF Weather Agency FMQ-19 (aka OS-21) as the basic system to ensure adequate logistics support. To meet special NASA requirements, the system has been modified to provide 1-second winds, additional ceilometers off both runway approaches, and a 120 minute (vs 30 minute) UPS backup. After several communication links are complete, the

system will become operational and turned over to the AF expected by FY 2006.

• Lightning Detection and Ranging (LDAR) System.

Since LDAR was originally developed as a research system in the late 1980s, its components are increasingly subject to obsolescence, and thus costs and the risk of system failure are increasing.

KSC worked with the Range to justify raising the priority of a replacement LDAR in the AF Space Command priority list. The AF and KSC worked with SLRS-C to overcome numerous obstacles: electromagnetic interference; NASA and AF requirements vs. COTS capabilities; site selection for antenna towers; takeover of COTS contractor by Finish international company; etc. Major unresolved KSC issues: transmission of LDAR data to SMG and NWS Melbourne; and an expected requirement to perform environmental impact assessments (EIS) on all seven antenna sites because of the location of two towers in marshlands. The EISs will delay antenna installation until FY 2006; testing until FY 2006, and project completion until FY 2007.

• TAL Atmospheric Sounding System (TASS).

The Radio Automatic Theodolite System (RATS) was used to provide SMG with upper level winds, temperatures and humidity at the Shuttle Transatlantic Abort Landing (TAL) sites in Spain, Morocco, and Gambia. RATS became obsolete when the manufacturer announced cessation of sonde production. A replacement system called TASS, a Global Positioning System (GPS) based Sippican W9000, was selected, procured, integrated and tested with the help of the Eastern Range. The initial system is now installed and operational. The Eastern Range owns, operates and maintains the system for NASA. In order to improve TASS' user friendliness, reliability, and accuracy, NASA will funded the ER to upgrade the Operating System from DOS to Windows, and upgrade the sondes in FY 2005.

• Sonic Lightning Locator (SOLLO).

The KSC Weather Office funded development of a new lightning detection system capable of locating lightning strikes in 4D with an accuracy of less than 5 meters (a considerable improvement over the 250-300 meter accuracy of our current lightning location system). Called SOLLO, it uses a sensor to detect the time of arrival of the electromagnetic pulse from a lightning strike, and then one elevated detector and three surface based detectors to measure the time of arrival of thunder from the lightning, to very accurately calculate the location of the lightning strike. SOLLO also calculates the amperage, rise time, and polarity of the strike. During FY 2004, KSC replaced/upgraded SOLLO components to enhance its capability to operate reliably in the corrosive KSC/ER environment. During the 2004 and 2005 spring/summer lightning season, KSC installed SOLLO systems at the Shuttle Launch Complex and a new technology development and testing facility for further testing.

• KSC/CCAFS Weather Observation Site Relocation.

The 24/7 official KSC/CCAFS Weather Observation Site is located in a very aging structure with its view of Shuttle Landing Facility (SLF) runway totally obscured. We convinced architects and managers of a project to build a new SLF air traffic control tower to include two floors for weather observers and equipment. The Range Technical Service Contractor (CSR) provided detailed specifications to ensure the final design met strict observing requirements. Tower project is complete; and move in completed FY 2005. The tower enables observers to provide much more accurate weather depictions over SLF, especially during rapidly changing conditions, thus improving aircraft, Space Shuttle and future RLV safety.

• Lightning Launch Commit Criteria (LLCC) Revision.

During analyses of Airborne Field Mill (ABFM) Program data, the Lightning Advisory Panel (LAP) concluded the radar definition of cloud edge, top and base in the LLCC was not sufficiently conservative. Based on ABFM measurements of electric fields high enough to trigger lightning with radar reflectivities as low as 5 dBZ, the LAP concluded the radar threshold needed to be lowered from 10 dBZ to 0 dBZ. The conclusion was reached one week before the launch of first Mars Rover on board a Delta.

A new definition was quickly staffed from the LAP thru 45 WS. and 45th Space Wing Safety, and the revision recommended at the Delta/Mars Rover Launch Readiness Review, two days before launch. Although Launch and Program managers are normally reluctant to accept last minute changes to procedures, we emphasized the revision was a safety issue and they accepted the change exactly as proposed.

• Columbia Accident Investigation.

The entire NASA and ER weather communities (KSC, JSC/SMG, MSFC, GSFC, LRC, and 45 WS) were deeply involved supporting the Space Shuttle Columbia accident investigation. Weather analyses were crucial to: identifying likely debris impact locations over the western and central U.S.; characterizing the atmosphere during reentry, beginning in the very data sparse upper Mesosphere; identifying possible anomalous wind shears during launch ascent; analyzing Columbia's exposure to the atmosphere during the 39 days Columbia was on the launch pad; and numerous engineering studies. NOAA/NWS also provided considerable help.

• Helios Accident Investigation.

NASA's premier solar-powered research aircraft (Helios) crashed just west of Barking Sands, Kauai in late June 2003. The KSC Weather Office participated on the Mishap Board along with Dr. John Brown from NOAA/Forecast Systems Lab. Due to Helios' many unique design and power characteristics, it had many very complex stability and control physics and characteristics.

Initial research revealed little was known about the atmosphere's behavior west of Kauai, specifically the atmosphere's combined response to the wake turbulence from the Trade Wind flow over the island, shear lines from air flowing around Kauai, sea breezes, and the large scale pattern. Thus the Weather Office contracted with NCAR and the University of Hawaii to perform high resolution atmospheric numerical model simulations to try to understand the atmosphere Helios encountered. In addition, the University of Hawaii designed and implemented a very low budget, aircraft data gathering program offshore of Barking Sands, Kauai, to measure wind and temperature profiles, and turbulence features. The aircraft data was used to understand small-scale features and to validate results from NCAR's high resolution model simulations. The final Helios Mishap Board report was released to the public.

SUPPORTING RESEARCH

NASA's Earth Science program is dedicated to the utilization of space technology and the pioneering of the use of global satellite measurements to improve human understanding of our Home Planet and thus inform economic and policy decisions and advance operational services of benefit to the Nation. The program is responsive to several Congressional Mandates and Presidential Initiatives.

Perhaps more than any other human activity, several centuries of progress in flight and advances in the space-related technology have steadily changed our perception of the Earth as a home planet. Satellite measurements of essential characteristics have enabled human understanding of the Earth as a system of tightly coupled parts. It is now clear for example that the characteristics of Earth's atmosphere so critical to human habitability are maintained by complex and tightly coupled circulation dynamics, chemistry, and interactions with the oceans, ice and land surface; all driven by solar radiation and gravitational forces. We live on a planet undergoing constant change due to natural phenomena and our own activities, and to maintain and improve quality of life on Earth, we need continuous global observations of variability and change analyzed to reveal the forces involved, the nature of the underlying processes and how these are coupled within the Earth system. To inform resource management decisions and policies we need ongoing predictions derived from Earth observations to expose the responses that determine further change. Thus, NASA's strategic goal: "study planet Earth from space to advance scientific understanding and meet societal needs" is expressed by the fundamental question: "How is the Earth changing and what are the consequences for life on Earth?"

NASA's Earth Science programs are essential to the implementation of three major Presidential initiatives:

- Climate Change Research (June 2001),
- Global Earth Observation (July 2003), and
- the Vision for Space Exploration (February 2004).

The first is the subject of the U.S. Climate Change Science Program (CCSP). The second is related, and focuses on national and international coordination of Earth observing capabilities to enhance their use in meeting important societal needs. An Earth Observation Summit in Brussels in February 2005, adopted a ten year plan for a Global Earth Observation system of systems. The third initiative uses NASA's observing technologies and knowledge of Earth as a planet to aid in the Nation's exploration of worlds beyond. NASA's unique role in these coordinated efforts is to advance remote sensing technology and computational modeling for scientific purposes, and facilitate the transition of mature observations and technologies to partner agencies that provide essential services using Earth science information.

The complexity of the Earth system, in which spatial and temporal variability exists on a range of scales, requires that an organized scientific approach be developed for addressing the complex, interdisciplinary problems that exist, taking good care that in doing so there is a recognition of the objective to integrate science across the programmatic elements towards a comprehensive understanding of the Earth system. In the Earth system, these elements may be built around aspects of the Earth that emphasize the particular attributes that make it stand out among known planetary bodies. These include the presence of carbon-based life; water in multiple, interacting phases; a fluid atmosphere and ocean that redistribute heat over the planetary surface; an oxidizing and protective atmosphere, albeit one subject to a wide range of fluctuations in its physical properties (especially temperature, moisture, and winds); a solid but dynamically active surface that makes up a significant fraction of the planet's surface; and an external environment driven by a large and varying star whose magnetic field also serves to shield the Earth from the broader astronomical environment. The resulting structure is comprised of six interdisciplinary science Focus Areas:

- Atmospheric position,
- Carbon Cycle and Ecosystems,
- Water and Energy Cycle,

- Climate Variability and Change,
- Weather and Earth Surface, and
- Interior

These six focus areas include research that not only addresses the challenging hierarchy of science questions but drives the development of an Earth observing capability and associated Earth system models as well.

NASA conducts Earth science research within a larger national and international context. This implies both opportunities for task sharing with partner agencies and the responsibility to seek optimal coordination of mutually supportive programs of these national and international partners. In particular, NASA has been actively seeking the cooperation of operational agencies in the US (DOD, NOAA, USGS) and elsewhere to ensure the long-term continuity of key environmental measurements in the long term. To achieve this goal, NASA will promote the convergence of the operational observation requirements of partner agencies with its research data needs for systematic observations, share the cost of new developments, and develop precursor instruments and spacecraft technologies for future operational application missions. NASA will also encourage the continuing involvement of scientific investigators in the calibration and validation of operational measurements, the development of more advanced information retrieval algorithms, and the analysis of operational data records. From this perspective, the potential for serving operational needs or commercial-applications is a priority criterion for NASA Earth science programs.

Interagency and international partnerships are also important for maximizing the scientific value of any research while minimizing costs. The need for partnerships in process-oriented field measurement activities is crucial, especially when investigators' access to particular regions of scientific interest is needed. For space-based measurements, partnerships provide the opportunity for leveraging additional contributions onto those that would be made by NASA, and allow for benefiting from the technological and scientific skills resident in other agencies and countries, as well as access to information needed for validation under a broad range of biological and geophysical conditions. Partnership opportunities will typically be encouraged in all relevant solicitations as long as they are consistent with national policy objectives such as export control of sensitive technology. Commercial partnerships also provide the opportunity for NASA to obtain needed data or services, and NASA has committed to working with the private sector to avoid duplicating capability that already exists in it.

Since its inception, NASA has exploited satellite platforms to observe the Earth, providing a critical resource for Earth science research. As a result of growing research efforts, many measurements from space are now routine and essential. For example, satellite remote sensing has become indispensable for accurate weather forecasts and severe storm warnings. But other important measurements require new concepts that take advantage of advancing technology-many observations remain difficult to interpret. Earth science research drives NASA satellite missions, and the focus area roadmaps indicate major requirements for developing or extending satellite remote sensing.

Beginning with the launch of the Terra satellite in December 1999, NASA began to deploy an Earth observing system with the objective of collecting systematic, well-calibrated and validated, long-term measurements to characterize and detect change in the Earth system. A suite of polar-orbiting and low-inclination satellites, each carrying multiple sensors, linked to a data system for acquisition, processing, and distribution, provides numerous science data products with global coverage and repeated measurements of sufficient frequency and accuracy to detect change. With the launch of Aura in July 2004, NASA completed the deployment of the observing system that now provides a core set of data products to characterize the Earth system and to identify and track changes. In the future, measurements whose scientific value demand a data continuity spanning multiple mission lifetimes will be provided by NASA satellites or operational satellites operated by other agencies. In addition, satellites like GRACE, launched in March 2002, probe key Earth processes globally for the first time. The CloudSat and CALIPSO satellites, launched in April 2006, are recent additions to these highly focused exploratory measurement missions. A brief description of all operating NASA Earth Science satellites is provided below:

<u>ACRIMSAT</u>

The Active Cavity Radiometer Irradiance Monitor III (ACRIM III) instrument onboard ACRIMSAT monitors total radiant energy from the Sun. Measurements of total solar irradiance are directly relevant to the Climate Variability and Change science focus area. When combined with other scientific data, these measurements will help climatologists to improve their predictions of long-term climate. They extend the database initiated by ACRIM I in 1980. ACRIMSAT was launched on December 20, 1999, and is in an extended mission having exceeded its 5 year design life.

<u>Aqua</u>

Aqua, Latin for water, was named for the large amount of information that the mission collects about the Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. In addition to the Water and Energy Cycle science

focus area, its six optical and microwave sensors provide interdisciplinary measurements supporting the Climate Variability and Change; Weather; Carbon Cycle, Ecosystems and Biogeochemistry; and Atmospheric Composition science focus areas. It is the second, following Terra, of the series of large satellites devoted to characterizing the Earth system and identifying and tracking changes. It is a collaboration with Japan and Brazil. Aqua was launched on May 4, 2002, and is in its 6-year prime mission. Aqua was the first member launched of a group of satellites termed the Afternoon Constellation, or sometimes the A-Train. Envisioned to eventually comprise 6 satellites, the A-Train will provide synergistic measurements from multiple satellites that together will contain comprehensive information about key atmospheric components and processes related to climate change and atmospheric composition.

Aura

Aura, Latin for air, was named for the unique global view it provides of the Earth's atmosphere in direct support of the Atmospheric Composition science focus area. It additionally supports Climate Variability and Change science focus area. Aura's objective is to study the chemistry and dynamics of the Earth's atmosphere with emphasis on the upper troposphere and lower stratosphere by employing four optical and microwave instruments on a single satellite. It is the third, following Aqua, of the series of large satellites devoted to characterizing the Earth system and identifying and tracking changes. It is a collaboration with the UK, Netherlands, and Finland. Aura was launched on July 15, 2004, and is in its prime 6 year mission. Aura is the second member to joint the A-Train or Afternoon constellation of satellites.

Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO)

CALIPSO will help answer significant questions about the effects of thin clouds and aerosols on changes in the Earth's climate. Understanding these components will provide the more comprehensive data set that is essential for better understanding the Earth's climatic processes in support of the Climate Change and Variability science focus area. CALIPSO combines a laser radar (backscatter lidar) with passive infrared and visible imagers to probe the vertical structure and properties of thin clouds and aerosols. It is a collaboration with France. CALIPSO was launched on April 28, 2006, with CloudSat and is early in its prime 3 year mission. It flies within seconds of CloudSat in the A-Train formation to take advantage of its complementary millimeter-wave radar measurements of clouds.

CloudSat

CloudSat uses advanced radar to "slice" through clouds to see their vertical structure, providing a completely new observational capability from space. CloudSat is one of the first satellites to study clouds on a global basis. It will look at their structure, composition and effects in support of the Climate Change and Variability and Weather science focus areas. It is a collaboration with Canada. CloudSat was launched on April 28, 2006, with CALIPSO and is early in its prime 22 month mission. CloudSat maintains a close formation with Aqua and particularly CALIPSO, providing near-simultaneous and collocated observations with the instruments on these two A-Train satellites.

Earth Observing-1 (EO-1)

EO-1 is an advanced land-imaging mission to demonstrate new instruments and spacecraft systems. EO-1 validated technologies contributing to the significant reduction in cost of follow-on Landsat missions. It supports the Carbon, Ecosystems and Biogeochemistry science focus area. EO-1 was launched on November 21, 2000, and is in an extended mission having exceeded its 2 year design life.

Gravity Recovery and Climate Experiment (GRACE)

The primary goal of the GRACE mission is to accurately map variations in the Earth's gravity field. GRACE studies gravity changes due to surface and deep currents in the ocean; runoff and ground water storage on land masses; exchanges between ice sheets or glaciers and the oceans; and variations of mass within the earth. The tandem two satellite mission supports the Earth Surface and Interior, Climate Variability and Change, and Water and Energy Cycle science focus areas. GRACE maps the Earth's gravity fields by making accurate measurements of distance between the two satellites using high quality Global Positioning System (GPS) receivers and a microwave ranging system. It is a collaboration with Germany. Grace was launched on March 17, 2002, and is in its prime 5 year mission.

Ice, Clouds, and Land Elevation Satellite (ICESat)

ICESat's primary objective is to quantify ice sheet mass balance and understand how changes in the Earth' atmosphere and climate affect polar ice masses and global sea level. It also measures the distribution of clouds and aerosols, as well as surveying land topography, sea ice, and vegetation cover. ICESat observations support the Climate Variability and Change, Earth Surface and Interior, and Water and Energy Cycle science focus areas. The primary instrument is a laser altimeter. ICESat was launched on January 12, 2003, and is in an extended mission having exceeded its 3 year design life.

Jason

Jason is an oceanography mission to monitor global ocean circulation, improve global climate predictions, and monitor events such as El Nino conditions and ocean eddies. The Jason satellite carries a radar altimeter and continues the precise sea surface

height measurement record begun by the TOPEX/Poseidon mission in 1992. Jason measurements support the Climate Variability and Change science focus area. It is a collaboration with France. Jason was launched on December 7, 2001, and is in an extended mission having exceeded its 3 year design life.

Landsat 7

Landsat 7 systematically provides calibrated, multispectral, moderate resolution images of the Earth's continental and coastal areas with global coverage on a seasonal basis. It covers the U.S. every 16 days. These images form a unique resource for global change research and various applications. Landsat 7 measurements support the Carbon, Ecosystems and Biogeochemistry science focus area. Landsat 7 is a collaboration with the U.S. Geological Survey which took over spacecraft operations in the Fall of 2000. Landsat 7 was launched on April 15, 1999, and is in an extended mission having exceeded its 5 year design life.

Quick Scatterometer (QuikSCAT)

QuikSCAT records sea-surface wind speed and direction data for global climate research and operational weather forecasting and storm warning (Figure 3-NASA-1). These data support the Climate Variability and Change and Water and Weather science focus areas. It replaces the data lost by the failure of the Japanese Advanced Earth Observing Satellite (ADEOS) in 1997. SeaWinds, a radar scatterometer, is the main instrument on the QuikSCAT satellite. QuickSCAT was launched on June 19, 1999, and is in an extended mission having exceeded its 3 year design life.

SOlar Radiation and Climate Experiment (SORCE)

SORCE provides data continuity with ACRIMSAT and operational successors to ensure long-term systematic measurement of total and spectral (1-2000 nm) solar irradiance, the dominant energy source in the Earth's atmosphere and one of its primary climate variables. Its measurements support the Climate Variability and Change science focus area. SORCE was launched on January 25, 2003, and is in its prime 5 year mission.

Terra

Terra, Latin for land, provides global data on the state of the atmosphere, land, and oceans, as well as their interactions with solar radiation and with one another. Its name reflects an emphasis on observations of terrestrial surface features although its measurements have a truly interdisciplinary character. Terra measurements support the Atmospheric Composition; Carbon, Ecosystems and Biogeochemistry; Climate Variability and Change; Earth Surface and Interior; Water and Energy Cycle; and Climate Variability and Change science focus areas. Terra employs five optical instruments on a single satellite. It is the first, of the series of large satellites devoted to characterizing the Earth system and identifying and tracking changes. It is a collaboration with Japan and Canada. Terra was launched on December 18, 1999, and is in an extended mission having exceeded its 5 year design life.

Total Ozone Mapping Spectrometer (TOMS)-Earth Probe (EP)

TOMS-EP provides global measurements of atmospheric total column ozone and its variation on a daily basis. It continues a long-term data set of daily ozone of over two decades. Its measurements support the Atmospheric Composition science focus area. The single instrument, TOMS, is a second-generation backscatter ultraviolet sounder. TOMS-EP was launched on July 2, 1996, and is in an extended mission having exceeded its 2 year design life.

Tropical Rainfall Measuring Mission (TRMM)

TRMM monitors tropical and subtropical rainfall and the associated release of energy that helps to power the global atmospheric circulation shaping both weather and climate

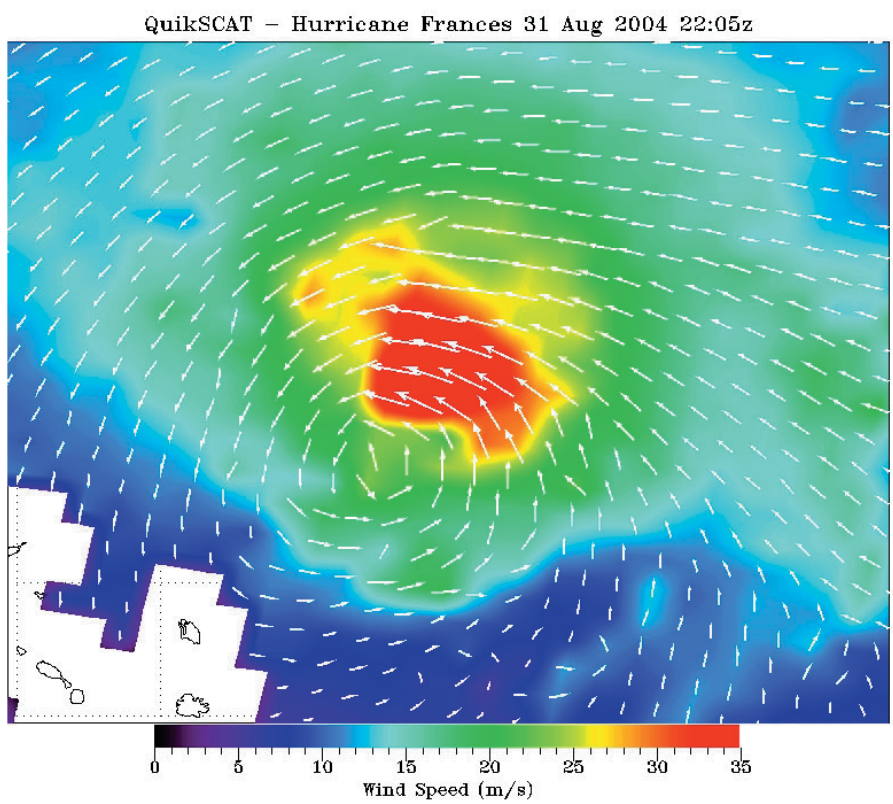


Figure 3-NASA-1. NASA QuickSCAT satellite view of Hurricane Frances (2004) in the Atlantic, showing structure of the low-level wind vortex.

around the world (Figure 3-NASA-2). Its measurements support the Climate Variability and Change, Water and Energy Cycle, and Weather science focus areas. The TRMM satellite carries the first precipitation radar flown in space and several microwave and optical radiometers. It is a collaboration with Japan. TRMM was launched on November 27, 1997, is in an extended mission having exceeded its 3 year design life.

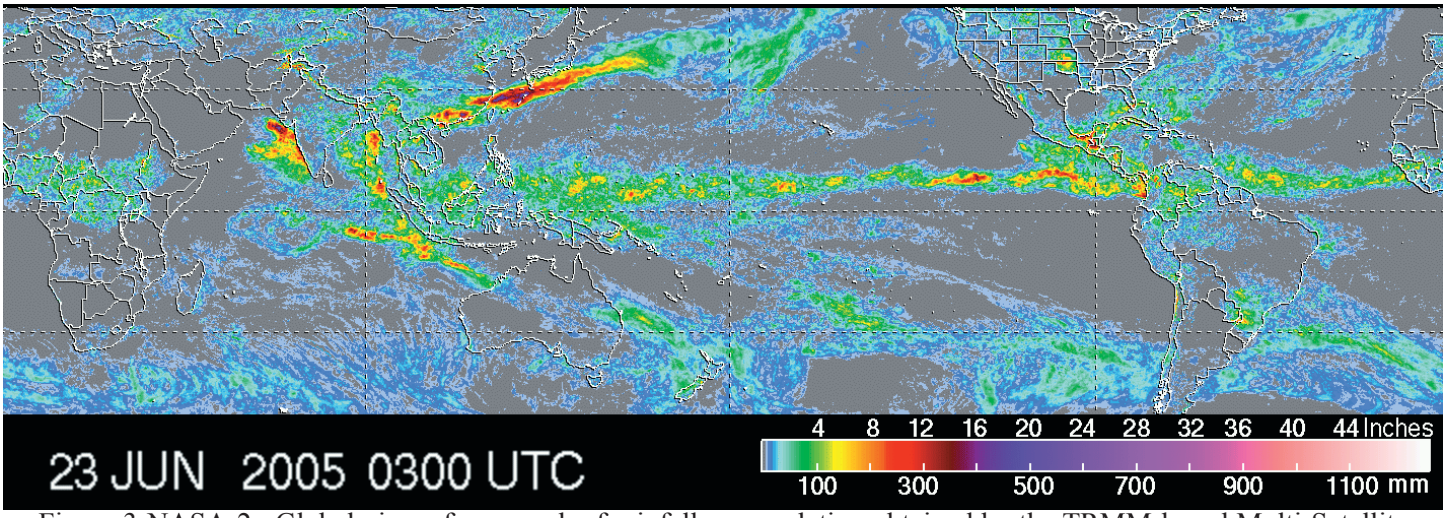


Figure 3-NASA-2. Global view of one week of rainfall accumulation obtained by the TRMM-based Multi-Satellite Precipitation Analysis.

NUCLEAR REGULATORY COMMISSION WEATHER PROGRAMS

The United States Nuclear Regulatory Commission (NRC) licenses and regulates all nuclear facilities subject to the Atomic Energy Act of 1954 as amended. The licensing and operation of these nuclear facilities require the identification of meteorological and climatological conditions that can affect the safe operation of the facility, and that provide input to the assessment of the radiological impacts of any airborne releases from the facility.

Within the NRC, the Offices of Nuclear Reactor Regulation and New Reactors conduct reviews of nuclear power plant siting, design, construction, and operation while the Offices of Nuclear Material Safety and Safeguards and Federal and State Materials and Environmental Management Programs conduct similar reviews of materials and waste facilities. These reviews include consideration of meteorological factors. The offices also conduct rulemaking to establish regulatory requirements. The NRC Regional Offices assure that licensing conditions are followed by NRC licensees. Together with the NRC Incident Response Operations, they also carry out NRC responses to nuclear facility emergencies.

The Office of Nuclear Regulatory Research (RES) conducts research in various categories to identify potential safety issues, and to prepare the agency to regulate the use of new technology. RES also develops regulatory guidance and participates in the development of criteria and consensus standards related to the protection of the public health and safety and the environment.

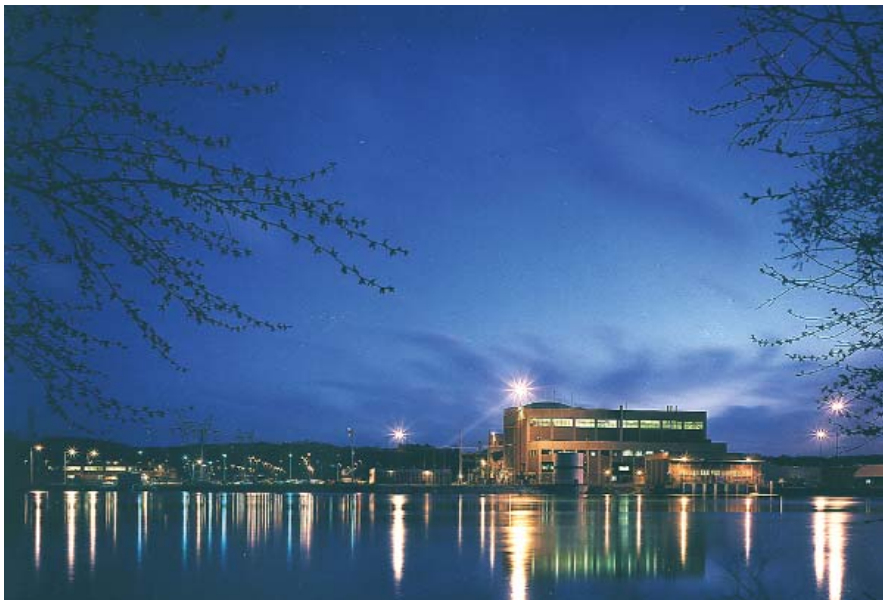


Figure 3-NRC-1. Fort Calhoun Nuclear Power Plant (NRC Image)

At the present time, the NRC is a user of meteorological information, rather than a performer of research in this field. Meteorological data will be used to assess radiological impacts of routine airborne releases from facilities, to evaluate the impact of proposed changes in plant design or operation on unplanned releases, and to evaluate new reactor designs or sites. Information of this type is also important for developing scenarios of climatological impacts on the isolation of long-lived nuclear wastes. The NRC also maintains an interest in the transport and dispersion of airborne, hazardous, nonradioactive materials, and the effects of extreme meteorological events on the safe operation of nuclear facilities.

NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is an independent agency of the Federal Government established to promote and advance scientific and engineering progress. The NSF sponsors and funds scientific and engineering research and education projects and supports cooperative research to gain new understanding of the behavior of the Earth's atmosphere and oceans. NSF does not itself conduct research but funds research performed by scientists at universities and other entities. In addition, NSF provides support for the maintenance and operation of the National Center for Atmospheric Research (NCAR) which is devoted to large-scale atmospheric research projects conducted in cooperation with universities and other Federal, state and/or local organizations.

The Division of Atmospheric Sciences manages NSF's basic atmospheric research support. This research focuses on new and fundamental knowledge needed to better understand the atmosphere and related sciences and to manage atmospheric science programs including natural disaster reduction, space weather, global change, and air quality.

NATURAL DISASTER REDUCTION

NSF supports fundamental and applied research to address weather phenomena that are either life threatening or economically disruptive. Focus areas include:

- Better understanding and forecasting of hurricane track and intensity;
- Better quantitative precipitation forecasting and estimation;
- Optimal use of observations in numerical models; and
- The societal/economic impacts of improved weather information.

The total research support for FY 2006 was approximately 14 million. A major activity in FY 2006 was the NSF/NOAA joint program entitled, Rainband Intensity Experiment (RAINEX). This project was focused on obtaining a better understanding of the impact of internal tropical storm dynamics on storm intensity. An excellent data set was gathered including data from hurricanes Katrina and Rita. Analysis of this data set is ongoing. In FY 2007, support is expected to remain at the same level as in FY 2006.

SPACE WEATHER

NSF supports research under the National Space Weather Program (NSWP). The objective of the NSWP is to perform the research and technology transfer needed to improve the specification and forecasts of space weather events that can cause disruption and failure of space borne and ground based technological systems and can endanger human health. Examples of NSF support of space weather include conducting a highly successful competition for space weather research grants and providing support for the Center for Integrated Space Weather Modeling (CISM), a multi-institutional effort led by Boston University and dedicated to providing advance warning of potentially harmful space weather events. NSF NSWP support in FY 2006 is about $14 million and is expected to be about the same in FY 2007.

GLOBAL CHANGE

Under the United States Climate Change Research Program, NSF supports research and related activities that advance fundamental understanding of dynamic, physical, geochemical, biological, and socioeconomic systems as well as interactions among those systems. In addition to research on Earth system processes and the consequences of changes in those systems, NSF facilitates data acquisition and data management activities necessary for basic research on global change, promotes the enhancement of modeling designed to improve representations of Earth system interactions, and develops advanced analytic methods to facilitate fundamental research. NSF also supports fundamental social and economic research on the general processes used by governments and other organizations to identify and evaluate different types of policies for mitigation, adaptation, and other responses to changing global environmental conditions. The total NSF FY 2006 funding for this area of research was about $195 million; in FY 2007, a modest funding increase is expected.

AIR QUALITY

NSF supported fundamental research in the area of air quality helps develop improved understanding of the sources, formation, atmospheric processing and fates of ambient air pollutants. Atmospheric oxidant species (and their precursors), sulfur dioxide, nitrogen oxides, carbon monoxide, fine particles (and their precursors), and acids are important atmospheric constituents that influence air quality, and in turn habitability, human health and climate. Field experiments, laboratory studies, instrument development, new methods of chemical analysis, and improved models of atmospheric chemical reaction mechanisms, transport and depositional phenomena are examples of air quality research supported by NSF. These categories provide scientific and technical input for management and control of atmospheric pollutant gases and particles.

NOTE: NSF budget data is not captured in Tables 2.1-2.5.

APPENDIX A

FEDERAL COORDINATION AND PLANNING

BASIS FOR FEDERAL COORDINATION PROCESS

In 1963, Congress and the Executive Office of the President expressed concern about the adequacy of coordination of Federal meteorological activities. In response, Congress directed in Section 304 of Public Law 87-843--the Appropriations Act for State, Justice, Commerce, and Related Agencies--that the Bureau of the Budget prepare an annual horizontal budget for all meteorological programs in the Federal agencies.

The Bureau of the Budget (now the Office of Management and Budget) issued a report entitled "Survey of Federal Meteorological Activities" (1963). The report described each agency's program in some detail, particularly its operational services, and detailed the relationship between the programs of the various agencies. The report revealed close cooperation but little evidence of systematic coordination. Based on this study, the Bureau of the Budget issued a set of ground rules to be followed in the coordination process. It established a permanent general philosophy for assignment and assessment of agency roles in the field of meteorology and set certain goals to be achieved by the coordination process. The Bureau of the Budget tasked the Department of Commerce (DOC) to establish the coordinating mechanism in concert with the other Federal agencies. It also reaffirmed the concept of having a central agency--the DOC--responsible for providing common meteorological facilities and services and clarified the responsibilities of other agencies for providing meteorological services specific to their own needs.

The implementation of these directives by DOC led to the creation of the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM) which operates with policy guidance from the Federal Committee for Meteorological Services and Supporting Research. The principal work in the coordination of meteorological activities and in the preparation and maintenance of Federal plans is accomplished by the OFCM staff with the advice and assistance of the Interdepartmental Committee for Meteorological Services and Supporting Research, and over 30 program councils, committees, working groups, and joint action groups.

MISSION OF THE OFFICE OF THE FEDERAL COORDINATOR FOR METEOROLOGY (OFCM)

The mission of the OFCM is to ensure the effective use of Federal meteorological resources by leading the systematic coordination of operational weather requirements, services, and supporting research, among the Federal agencies. The high level focus and output as a result of carrying out this mission includes needs and requirements; issues and problems; studies, reports, plans, and handbooks; and crosscut reviews, assessments, and analyses.

OFCM's objectives in carrying out its mission include:

- Documenting agency programs and activities in a series of national plans and reports that enable agencies to revise/adjust their individual ongoing programs and provide a means for communicating new ideas and approaches to fulfill requirements.
- Providing structure and programs to promote continuity in the development and coordination of interagency plans and procedures for meteorological services and supporting research activities.
- Preparing analyses, summaries, or evaluations of agency meteorological programs and plans that provide a factual basis for the Executive and Legislative branches to make appropriate decisions related to the allocation of funds.
- Reviewing Federal weather programs and Federal requirements for meteorological services and supporting research. This review may suggest additions or revisions to current or proposed programs, or identify opportunities for improved efficiency, reliability, or cost avoidance through coordinated actions or integrated programs.

As detailed in the report which follows, this has been an excellent year for OFCM in carrying out its interagency activities. The accomplishments of FY06 were substantial and meaningful for the nation, and the foundation has been placed for a similarly productive FY07.

FEDERAL COMMITTEE FOR METEOROLOGICAL SERVICES AND SUPPORTING RESEARCH

The Federal Committee for Meteorological Services and Supporting Research (FCMSSR), established in 1964, provides policy-level agency representation and guidance to the Federal Coordinator to address agency priorities, requirements, and issues related to services, operations, and supporting research, and also resolves agency differences that arise during the coordination of meteorological activities and the preparation of Federal plans. The Under Secretary of Commerce for Oceans and Atmosphere, who is also the Administrator of the National Oceanic and Atmospheric Administration (NOAA), serves as the FCMSSR Chairperson.

The 15 Federal agencies that engage in meteorological activities, or have a need for meteorological services, are represented on FCMSSR. The FCMSSR membership includes: DOC, DOD, DOT, the Departments of Agriculture (USDA), Energy (DOE), Homeland Security (DHS), Interior (DOI), and State (DOS), the Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), National Science Foundation (NSF), National Transportation Safety Board (NTSB), Nuclear Regulatory Commission (NRC), the Office of Science and Technology Policy (OSTP), and the Office of Management and Budget (OMB).

HIGHLIGHTS FOR FISCAL YEAR 2006 AND PLANS FOR FISCAL YEAR 2007

NATURAL DISASTER REDUCTION

INTERDEPARTMENTAL HURRICANE CONFERENCE

The OFCM annually hosts the Interdepartmental Hurricane Conference (IHC) to provide a forum for the responsible federal agencies, together with representatives of the user communities such as emergency management, to review the nation's hurricane forecast and warning program and to make recommendations on how to improve the program. The OFCM hosted the 60th IHC in Mobile, Alabama, March 20-24, 2006. The theme of the 2006 conference was *Hurricane Season 2006: Building on the Historic 2005 Season*. The conference attendance was more than 240; for the seventh consecutive year, attendance has exceeded 200. VADM Conrad C. Lautenbacher, Jr., USN (Ret.), Under Secretary of Commerce for Oceans and Atmosphere and Administrator of the National Oceanic and Atmospheric Administration (NOAA), set the tone for the meeting during his Monday afternoon keynote address-Power of Partnerships: Prediction and Protection, noting that the only way to protect lives, property, and the economic well-being of our citizens is through partnerships. As a result, the importance of building partnerships became the central theme of the conference which the attendees took to heart. Objectives of the 2006 IHC included the following: review the nation's tropical cyclone forecast and warning program from end-to-end and update the *National Hurricane Operations Plan for 2006*; evaluate lessons learned from the 2005 hurricane season, with a focus on Hurricanes Dennis, Katrina, Rita, and Wilma; examine the results of the Joint Hurricane Test Bed (JHT) as a model for transitioning successful research results into operations; review the federal priorities for tropical cyclone research and development for the next decade, to include relevant social science issues; examine the needs and requirements for future tropical cyclone surveillance and reconnaissance observations; and evaluate changes in forecast and warning messages needed to improve public awareness, preparedness, and response. The IHC once again proved to be an extremely valuable forum to bring the operational and research communities together to produce the best possible tropical cyclone forecast and warning program, and to address the needs of the federal agencies and user communities that have a stake in the nation's tropical cyclone program. Actions resulting from the conference are: (1) publish the *2006 National Hurricane Operations Plan*; (2) through the Joint Action Group for Tropical Cyclone Research (JAG/TCR), further refine the draft strategic research plan for tropical cyclones based on the input received during the 60th IHC workshop; (3) develop a Strategic Plan for Improved Tropical Cyclone Reconnaissance Systems (ITCRS) (manned, unmanned, space-based, etc.); (4) facilitate bringing together the Web site owners from NOAA (e.g., Hurricane Research Division, National Hurricane Center), Navy, etc., to improve linkages for supporting research and development; and (5) adopt recommendations for action in a comprehensive effort to improve *getting the "right" message to the customer*. In May 2006, the 44th edition of the *National Hurricane Operations Plan (NHOP)*, which provides the basis for hurricane reconnaissance for the 2006 season and details federal agency responsibilities, operations, and procedures; products; aircraft, satellite, radar, and buoy data collection; and marine weather broad-

casts, was published based on the inputs and discussions from the 60th IHC. The comprehensive NHOP was critical to ensuring successful weather and reconnaissance operations for the 2006 hurricane season. The 2007 IHC is being planned for New Orleans, Louisiana.

TROPICAL CYCLONE RESEARCH AND DEVELOPMENT PLAN

Actions from previous meetings of the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) and Interdepartmental Hurricane Conferences (IHC) called for the preparation of a tropical cyclone strategic research plan. This is being accomplished by the OFCM Joint Action Group for Tropical Cyclone Research (JAG/TCR). JAG/TCR had available results from numerous past efforts which have outlined the tropical cyclone community's priorities and strategies which were vetted through many meetings and workshops. Examples of these, which detailed research challenges and priorities, operational needs, gaps, and potential solutions, include the U.S. Weather Research Program (landfalling hurricanes and Joint Hurricane Testbed), OFCM-sponsored Interdepartmental Hurricane Conferences, two Hurricane Weather Research and Forecasting (HWRF) model workshops, and activities of NOAA's National Weather Service and Office of Oceanic and Atmospheric Research. In addition, the tropical cyclone research workshop held in March 2006 at the 60th IHC, reviewed ongoing efforts of three complementary hurricane research projects. These included the NOAA Science Advisory Board (SAB) Hurricane Intensity Research Working Group (HIRWG), the National Science Foundation (NSF) National Science Board's (NSB) Task Force on Hurricane Science and Engineering (HSE), and the OFCM Joint Action Group for Tropical Cyclone Research which is preparing the document, *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead*. The plan notes that overarching tropical cyclone priorities that need further improvement are intensity and structure; track; other impacts (sea state, storm surge, precipitation, inland flooding); social science research and results; and intraseasonal and interannual variability. More specific examples of research priorities were identified as the role of inner core processes for intensification and weakening (e.g., eyewall replacement cycles, mixing); role of the ocean and oceanic heat content; value of high-resolution deterministic forecasts vs. ensembles; consideration of the extent to which the public understands terms such as "hurricane watch" and "hurricane warning" and whether these terms best convey these concepts; and consideration of how probabilistic forecasts can be structured to promote public understanding. OFCM will publish the *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead* in fall 2006. It will then focus on development of a *Strategic Plan for Improved Tropical Cyclone Reconnaissance Systems* (manned, unmanned, space-based, etc.).

NATIONAL HURRICANE CONFERENCE

OFCM participated in the 28th Annual National Hurricane Conference (NHC) in Orlando, Florida, April 10-14, 2006. The NHC is the nation's forum for education and professional training in hurricane preparedness. The primary goal of the NHC is to improve hurricane preparedness, response, recovery, and mitigation in order to save lives and property in the United States and the tropical islands of the Caribbean and the Pacific. In addition, the conference serves as a national forum for federal, state, and local officials to exchange ideas and recommend new policies to improve emergency management. On April 11, OFCM conducted a training session in conjunction with the conference. The theme of the training session was *Warning Messages: Improving Response*. The training session focused on hurricane messages and communication, and introduced a new proposed communications model that reflects the divergent information needs of various users. Included in the session was a review of recent social science research results, pertaining to hurricane response and, just as important, specific recommendations emergency managers and decision makers can use to improve hurricane response. Approximately 200 conference attendees participated in the training session, which validated the need to revisit the warning process. It was noted that messages, resulting in appropriate response, must come from credible sources, must be received, must be understood, must have personal meaning, should include action statements, often require confirmation, and are only successful if appropriate responses are possible. It was also emphasized that the results of social science research need to be an integral part of the hurricane forecast and warning program.

POST-STORM DATA ACQUISITION

The OFCM continued to coordinate, as required, timely post-storm data acquisition surveys in response to Presidentially declared natural disasters and other agency requirements to evaluate, for example, the impact on the coastal ecosystems. These natural disaster reduction efforts contribute to the determination of the intensity and magnitude of storms, and, in many cases, help to determine the extent of damage for use in Presidential disaster declarations. The additional data collected after hurricane landfall is also used in validating modeling efforts with both emergency management models (e.g., FEMA's HAZUS) and

hurricane storm-surge models (e.g., NOAA's SLOSH). These models are used in real time to assist decision makers in evacuation decisions and procedures. Post-storm data are also used to update FEMA Flood Insurance Rate Maps. In FY 2006, post-storm surveys were conducted for Hurricane Rita and after the April 7, 2006, tornado outbreak in central Tennessee.

URBAN METEOROLOGY

NATIONAL WILDLAND FIRE WEATHER NEEDS ASSESSMENT

An important contribution to urban meteorology during the period of this report is related to the National Wildland Fire Weather Needs Assessment which is being conducted by OFCM. The formation of the Joint Action Group for National Wildland Fire Weather Needs Assessment (JAG/NWFWNA) and conduct of the assessment is responsive to ICMSSR Action Item 2005-1.1 where ICMSSR "concurred that OFCM should move forward to form a Joint Action Group (JAG) under the Committee for Environmental Services, Operations, and Research Needs (CESORN), to review the needs and requirements for wildland fire weather information, to include identifying organizational responsibilities and addressing the following issues: data collection, fire weather research, weather forecast services, data assimilation, air quality, information dissemination, education and outreach, and user response." An abundance of accumulated biomass in forests and rangelands, persistent drought conditions, and encroaching urbanization are contributing to larger, more costly wildland fires; and to effectively manage and suppress wildland fires, fire managers need timely, accurate, and detailed fire weather and climate information. As examples, the 2003 wildland fires in southern California claimed 22 lives, destroyed 3,600 homes, burned 740,000 acres of land, and caused over $2 billion in property damage; and the grassland fires this year in Texas by June 1st had claimed 11 lives, destroyed 440 homes, and burned over 5 million acres. Another example is the fires in southern California in mid-July, which were started by lightning, and enhanced by dry conditions (drought) and fanned by strong winds. On June 22, 2006, California Governor Schwarzenegger signed an Executive Order to expand statewide firefighting efforts and called on Californians to take common sense fire prevention measures. An important benchmark is the June 2005 Western Governors' Association (WGA) meeting where they approved Policy Resolution 05-04: National Wildland Fire Weather Program. Within the policy, the WGA urged NOAA to have the OFCM complete a National Needs Assessment Report of federal, state, and local fire managers' needs for weather information in their wildfire and prescribed fire decision making processes and a framework to meet those needs by the National Weather Service and Predictive Services. The JAG/NWFWNA was established in December 2005 and has moved forward to conduct the assessment. Preliminary findings have been obtained in several areas including federal agency reactions, education and outreach, atmospheric and meteorological research concerns, user and stakeholder initial response, and social science aspects. Next steps include the interim assessment report (early results) to be completed in the fall of 2006; an OFCM Special Session on wildland fire weather and climate use in decision making at the 3rd International Fire and Ecology Congress, November 14, 2006, in San Diego, California; briefing to the Interdepartmental Committee for Meteorological Services and Supporting Research; continuing the fact survey effort; and the final product available during the spring 2007 which will be used to support the 2007 WGA conference.

ATMOSPHERIC TRANSPORT AND DIFFUSION RESEARCH AND DEVELOPMENT

OFCM developed an atmospheric transport and diffusion (ATD) implementation strategy for the recommendations for which OFCM has primary responsibility in the *Federal Research Needs and Priorities for Atmospheric Transport and Diffusion Modeling* (September 2004) report. The implementation strategy has three parts: (1) working with the agencies to identify and improve a baseline set of national ATD modeling capabilities; (2) helping the agencies implement a common framework for model development and evaluation; and (3) recommending criteria for multifunctional joint urban test beds ["urban" describes a metropolitan area and its interfaces with surrounding areas]. In accordance with this, OFCM formed a Joint Action Group for the Joint Urban Test Beds (JAG/JUTB) under the Working Group for Urban Meteorology (WG/UM); and this joint action group met January 24, March 1-2, and June 15, 2006, and is continuing work to develop an operational concept document for multifunctional joint urban test beds to provide services and data to model developers, test and evaluation personnel, and users. The joint urban test beds will support the following functional areas: severe weather (e.g., hurricanes, tornadoes, heat waves and cold spells, drought, and wildland fires), homeland security (dispersion of hazardous materials), climate, air quality (e.g., particulate matter aerosols), and water quality (e.g., deposition of airborne contaminants on water sources and waterborne transport of contaminants).

GEORGE MASON UNIVERSITY ATMOSPHERIC TRANSPORT AND DISPERSION MODELING CONFERENCE

George Mason University (GMU),

Fairfax, Virginia, conducted its 10th Annual Conference on Atmospheric Transport and Dispersion Modeling, August 1-3, 2006. The OFCM cosponsored the event, together with the Joint Science and Technology Office for Chemical and Biological Defense, Defense Threat Reduction Agency (DTRA); the Naval Surface Warfare Center, Dahlgren Division (NSWCDD); and George Mason University. Technical topics of interest for the conference were: new developments in basic theories of boundary layer models and transport and dispersion models; urban-scale meteorological and dispersion experiments and models; computational fluid dynamics (CFD) model theory and applications; field experiments and laboratory experiments concerned with boundary layer studies and turbulence and dispersion studies; mesoscale meteorological modeling for input to transport and dispersion models; the use of remote sensing technology in boundary layer and transport and dispersion studies; model evaluation methods, uncertainty/sensitivity analyses, and risk assessments; improvements in model inputs (e.g., land-use data, 3-D building data) and output visualizations; and methods and criteria for emergency response and decision making.

The OFCM conducted a special session related to the OFCM's ongoing work with other members of the federal meteorological community to implement the recommendations in the report, *Federal Research Needs and Priorities for Atmospheric Transport and Diffusion Modeling*. The special session provided much information on joint urban test beds, including the history and status of the joint urban test bed effort, the importance of user involvement, the importance of test beds for air quality and for regulatory work done by the Environmental Protection Agency, the efforts of the Centers for Disease Control and Prevention to monitor health impacts, the needs of emergency managers and responders, research perspectives, data management needs, and the importance of more complete understanding of weather in the urban environment.

CLIMATE

OFCM supports the U.S. Climate Change Science Program (CCSP). OFCM arranged for Dr. James R. Mahoney, former Director of the CCSP, to brief the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) so that member agencies can stay abreast of the program and coordinate priorities for atmospheric requirements through OFCM for inclusion in CCSP. Further, OFCM used its infrastructure to reach out and invite many government, private, and academic individuals to attend the November 14-16, 2005, *CCSP Climate Science in Support of Decision Making* workshop, and this resulted in substantially increased attendance of the workshop; and OFCM provided interagency funding support for an evening poster session of the workshop. OFCM also prepared results of a Climate Services Survey to identify new climate products and services that have been developed and implemented since the Board on Atmospheric Sciences and Climate defined "climate services" in 2001 as "the timely production and delivery of useful climate data, information, and knowledge to decision makers." This definition was adopted by Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) agencies. The results of the survey were forwarded to the Director of the CCSP just prior to the beginning of FY 2006. And the Federal Coordinator, through his participation on the Committee on Environment and Natural Resources (CENR), reviewed and commented on and provided concurrence with the U.S. CCSP Synthesis and Assessment Product 1.1, *Temperature Trends in the Lower Atmosphere-Steps for Understanding and Reconciling Differences*, a report by the U.S. CCSP and the CENR Subcommittee on Global Change Research (SGCR).

OPERATIONAL PROCESSING

OFCM's activities regarding Operational Processing Centers (OPC) continue opportunities to improve processing and backup capabilities of NOAA's National Centers for Environmental Prediction and Office of Satellite Data Processing and Distribution, the Air Force Weather Agency, and the U.S. Navy's Fleet Numerical Meteorology and Oceanography Center and Naval Oceanographic Office. Efforts continue to improve backup support and capabilities and to coordinate preparation for the implementation of the Weather Research and Forecasting (WRF) modeling system, in accordance with the *National Concept of Operations Framework for the Operational Processing Centers*, which is contained in an April 1, 2004, memorandum of agreement signed by the directors of the OPC's. Of particular significance during this period is the establishment of a National Operational Processing Centers (NOPC) Program Council within the OFCM coordinating infrastructure, to help achieve national priorities by focusing agency efforts and leverage resources to gain the maximum return. This was in response to the OPC Directors' determination that effectively coordinating the OPCs' efforts and providing the resources to support those efforts necessitated high-level policy guidance and oversight. OFCM's previously existing Committee for Operational Processing Centers (COPC) and its Working Group for Cooperative Support and Backup (WG/CSAB) and joint action groups for operational community modeling, centralized communications management, and operational data acquisition for assimilation, were placed under the new NOPC Program Council.

ANNUAL FEDERAL PLAN

In October 2005, the OFCM issued *The Federal Plan for Meteorological Services and Supporting Research-Fiscal Year 2006*. The Federal Plan is congressionally mandated and is a one-of-a-kind document which articulates the meteorological services provided and supporting research conducted by agencies of the federal government. The Federal Plan helps to reduce overlap and duplication among the agencies. It is a comprehensive publication that documents proposed programs for FY 2006 and reviews agency programs in FY 2005. The feature article for the FY 2006 Annual Federal Plan focuses on the federal agencies' meteorological activities related to minimizing the impact of wildland fires on the urban environment; its title is *Living with Wildland Fire in the Urban Environment*. The article summarizes the causes of wildland fires, describes their impacts on urban communities, reviews some activities undertaken by federal agencies to minimize the impacts, and recommends next steps to address these impacts effectively. The feature article for the FY 2007 Annual Federal Plan focuses on tropical cyclone research.

WEATHER INFORMATION FOR SURFACE TRANSPORTATION

Since 1998, OFCM has made weather services and research and development (R&D) activities supporting the surface transportation community a priority for the federal meteorological community. In December 2002, OFCM published the comprehensive report, *Weather Information for Surface Transportation-National Needs Assessment Report*, which provides the first ever compilation and analysis of weather support needs across six surface transportation sectors (roadway, railway, transit, marine transportation, pipeline systems, and airport ground operations). In August 2004, OFCM established the Working Group for Weather Information for Surface Transportation (WG/WIST) to develop both a WIST R&D Plan and a WIST Implementation Plan. More recently, OFCM conducted two WIST workshops June 6-7 and June 13-14, 2006, with the objectives to: (1) help determine the priorities for the surface transportation weather information research needed to provide improved weather information and services to the surface transportation community; (2) gather and crossfeed information concerning ongoing or planned (next 3 years) surface transportation weather-related research and development; and (3) hear from workshop attendees on what they see as a vision (3-10+ years) on how weather information will be used to optimize surface transportation operations and safety, and what specific hurdles must be overcome to reach such a vision. Information from these workshops is being reviewed and organized to support continued progress in this important area, which will lead to the WIST R&D Plan and WIST Implementation Plan mentioned above. During the period of this report, OFCM also attended the National Research Council Transportation Research Board (TRB) 85th Annual Meeting in Washington, D.C., January 22-26, 2006; provided a WIST presentation at the 86th American Meteorological Society (AMS) Annual Meeting, Atlanta, Georgia (January 29 - February 2, 2006); and attended the Intelligent Transportation Society of America (ITS-A) 2006 Annual Meeting and Exposition in Philadelphia, Pennsylvania (May 7-9, 2006). And in August 2006, OFCM published the report, *Weather Information for Surface Transportation-Update on Weather Impacts and WIST Results*. This update focuses on the status of transportation weather issues in the nation and the results achieved since the first WIST report in 2002. It also highlights areas where further steps can be made in the near term. When statewide transportation incident reporting systems are implemented, we will be able to monitor, assess, and manage transportation weather risks, as well as evaluate the benefits of WIST-informed transportation decisions. R&D programs are in progress to improve warnings and decision support systems, implement weather-responsive traffic management in communities, and provide the observational support necessary for location-specific WIST.

AVIATION WEATHER

A project which is underway in the area of aviation weather support includes the development of The *National Volcanic Ash Operations Plan for Aviation and Support of the International Civil Aviation Organization International Airways Volcano Watch (NVOPA)*. This plan, projected be completed in the fall of 2006, is the national operations plan in support of observing, tracking, monitoring, forecasting and reporting volcanic ash in the atmosphere that affects the safety of flight operations in the U.S. National Airspace System (NAS). It identifies the federal agencies that implement these actions and describes their responsibilities, procedures, actions, and message formats. It also provides information on how the Federal Aviation Administration (FAA) meets its obligations to the International Airways Volcano Watch, sponsored by the International Civil Aviation Organization. Participating agencies include, in addition to FAA, the Department of Commerce National Oceanic and Atmospheric Administration's National Environmental Satellite, Data, and Information Service, the National Weather Service, and the Office of Oceanic and Atmospheric Research; the Department of Defense U.S. Air Force; and the Department of Interior's U.S. Geological Survey. The National Aeronautics and Space Administration (NASA) and the

Smithsonian Institution also provide support to the federal agencies through extending the benefits of earth science research in the areas of volcanic ash monitoring and tracking.

The OFCM continues to facilitate the continuation of interagency funding for the acquisition of automated meteorological observations from aircraft in partnership with several major U.S. commercial airlines.

The OFCM attended the National Business Aviation Association, Inc., and Friends and Partners in Aviation Weather Annual Meeting and the FAA's Aviation Weather Technology Transfer meeting held in Orlando, Florida, in November 2005. OFCM also participated in the NASA Weather Accident Prevention project review in September 2005, and continued to implement the National Aviation Weather Program during FY 2006. The federal interagency National Aviation Weather Program has resulted in a major reduction of weather-related accidents. The program remains on track toward meeting the established goal to reduce weather-related accidents by 80 percent by 2007. The OFCM continues to monitor progress in meeting this goal by monitoring weather-related aviation accident events and trends. *A National Aviation Weather Program Mid-Course Assessment* was completed in August 2003. OFCM will complete a final assessment in 2007, the ten year point of the National Aviation Weather Program.

The OFCM continues to implement the National Aviation Weather Program. OFCM is a member of the executive council of the interagency Joint Planning and Development Office Weather Integrated Product Team, and has monitored the early development of the Next Generation Air Transportation System concept of operations with special emphasis on how weather support will be integrated into the concept of operations for the overall NAS 2025.

SPACE WEATHER

It was noted at the November 16, 2004, and December 1, 2004, meetings of the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) and Federal Committee for Meteorological Services and Supporting Research (FCMSSR), respectively, that the National Space Weather Program (NSWP) was nearing the end of its 10-year period to accomplish its overarching goal to achieve an active, synergistic, interagency system; providing timely, accurate, and reliable space weather warnings, observations, specifications, and forecasts by 2007. It was also noted that it was time to perform an interagency assessment to look at the progress toward meeting its goals. A National Space Weather Program Assessment Committee was formed by OFCM to perform the assessment, which was led by Dr. Louis J. Lanzerotti, Distinguished Research Professor, Center for Solar-Terrestrial Research, New Jersey Institute of Technology. The charge to the Assessment Committee was to review the NSWP to quantify and document the progress toward meeting the NSWP stated goals in observations, research, modeling, transition of research to operations, and education and outreach; to see if the program is still on target and moving in the direction pointed to by the Strategic Plan; to determine whether the strategic goals should be adjusted at this time based on emerging/evolving requirements; and to suggest a way ahead which will form a basis for a new strategic plan covering the next 10 years. The committee's activities in conducting the assessment included briefings at OFCM; visits to the National Security Space Office, National Reconnaissance Office, NOAA's Space Environment Center, U.S. Geological Survey, Air Force Space Command, Air Force Weather Agency, Air Force Space Weather Operations, STRATCOM, and Air Force Research Laboratory; community and user questionnaires; and issuance of a September 2005 interim report. Important reference sources were the *National Security Space Architecture 2000: Space Weather Architecture*; U.S. Department of Commerce Service Assessment, April 2004; and the National Academies report, *The Sun to the Earth-and Beyond: A Decadal Research Strategy in Solar and Space Physics*, 2002.

In its *Report of the Assessment Committee for the National Space Weather Program* (June 2006), the Assessment Committee concluded that, since the program's inception in 1995, it has had a number of noteworthy achievements, most of which likely would not have been attained without the program's existence. The committee also found shortfalls in the program. Based on the conclusions of the committee as contained in the report, continuation of the NSWP is strongly warranted because of the enormous potential to enhance the nation's space weather mission over the next 10 years through improved operational capabilities, which capitalize on the transition of innovative research. Moving NOAA's operational space weather prediction center (i.e., the Space Environment Center) from its research organization to the National Weather Service was a positive step to improve operational focus within the NSWP. The committee made specific recommendations to further strengthen the NSWP in four key areas. The critical findings and recommendations to strengthen the NSWP are:

1. To centralize program management, set national funding priorities, and increase the effectiveness of the NSWP:

- Establish a space weather expert as the permanent Executive Secretary to the Committee for Space Weather under the National Space Weather Program Council.

• Establish a focal point for the program in the Office of Science and Technology Policy (OSTP)/Office of Management and Budget (OMB).

• Create a joint, cross-agency, space weather organization, the "Center for Space Weather Research to Operations."

2. For continuity of data sources critical to space weather forecasts and operations:

• Develop and execute strategy and funding for L1 sensor continuity.

• Maintain critical ground-based assets such as USGS magnetic observatories.

3. To strengthen the science-to-user chain:

• Maintain and strengthen both targeted and strategic space weather research.

• Enhance emphasis and resources for transition of models to operational users.

• Increase the private sector role in supplying products and services.

4. To emphasize public and user awareness of space weather for critical national needs:

• Quantify the national benefits that arise from the NSWP.

• Enhance academic and professional education programs for new space weather professionals.

It was agreed that the *Report of the Assessment Committee for the National Space Weather Program* should proceed for consideration by the National Space Weather Program Council (NSWPC), and that the Program Council should be the executive agent for FCMSSR for continuing activities in this area. And, at its July 19, 2006, NSWPC meeting, Action Item 2006-1.1 was agreed to stating "The National Space Weather Program Council (NSWPC) accepted the report as an extremely important resource in moving the National Space Weather Program (NSWP) forward over the next 10 years and tasked the Committee for Space Weather (CSW) to prepare new strategic and implementation plans that stress the importance of improving our operational capabilities to provide space weather products and services with the support of a viable research program and an effective mechanism to transition proven research results into operations." Additional action items were approved concerning OFCM investigation of oversight of the NSWP in the Office of Science and Technology Policy (OSTP) and in the Office of Management and Budget (OMB), and the possibility of establishing a joint working group for all cooperating NSWP agencies similar to that described for NASA and NOAA in the NASA Authorization Act of 2005, Section 306; and identification of report recommendations that the CSW can move forward on right away, agency specific recommendations, and recommendations that require more study.

The OFCM also participated in Space Weather Week April 25-28, 2006, in Boulder, Colorado. Space Weather Week was sponsored by NOAA Space Environment Center and partners, and is for users and researchers interested in space weather.

PHASED ARRAY RADAR

The OFCM Joint Action Group for Phased Array Radar Project (JAG/PARP) recently completed the report, *Federal Research and Development Needs and Priorities for Phased Array Radar* (June 2006). It is responsive to ICMSSR Action Item 2004-2.3 where ICMSSR supported the joint action group's "continued work to identify and document the potential needs and benefits that phased array radar and an adaptive radar sensing strategy would address, and to integrate those identified needs into a multiagency-coordinated R&D plan that would focus R&D efforts on meeting each agency's need." In the MPAR national vision, the National Radar Network will be the critical observing system supporting public safety, homeland security, and the transportation sector for decades to come; there is a need to replace the aging fleet of 526 conventional mechanically scanning radars over the next 20 years with 300+ MPAR radars; MPAR can provide simultaneous air and weather surveillance from a single radar site; and with the consolidation of multiple single-mission radars into MPAR we can reduce the national radar fleet by more than 40 percent. The scalable (modular construction) MPAR can perform weather surveillance, aircraft tracking, non-cooperative aircraft tracking, and other specialized functions. The JAG/PARP has determined that MPAR has the potential to exceed present radar capabilities and meet stated user needs; there would be a significant increase in tornado lead times; there are no serious hardware technical challenges; and a 7- to 10-year intensive research and development effort will be required, and the estimated cost of this is $200 million. The lifecycle cost savings of the MPAR over the 526 conventional radars, would be $5 billion. MPAR's potential improvements include: agile beam-forming allows multi-function applications for optimum weather, aircraft surveillance, as well as specialized functions such as tracking chemical/biological plumes, volcanic ash, birds, wildfire debris, etc.; improved coverage in the boundary layer and clutter suppression; capability to perform intensive radar interrogation ("staring") simultaneously with all-sector surveillance; rapid refresh rate-improved spatial and temporal resolution, especially of severe weather events; and graceful degradation, greater system reliability, and simplified logistics. The report *Federal Research and Development Needs and Priorities for Phased Array Radar* estimated needed research and development funding to be $215 million over 9 years to meet the replacement

opportunity. This would support the research needed to reduce risk, determine the capability of MPAR to meet multiple user needs concurrently, develop a full MPAR prototype, and perform a cost analysis to determine system affordability. Delays in performing the necessary MPAR research, development, and testing may mean missed opportunity to replace legacy radars. At its July 18, 2006, meeting, ICMSSR decided that an MPAR interagency working group should be established within the OFCM infrastructure with a defined charter to develop a strategy to address the key findings and recommended next steps in the MPAR report, and agency comments from the ICMSSR meeting.

ATMOSPHERIC RESEARCH AND DATA ASSIMILATION/DATA MANAGEMENT

Advances in data assimilation are key to meeting virtually any forecast goal relating to model performance. It was stated in the *Strategic Plan for the U.S. Integrated Earth Observation System* (April 2005) that "In order to take the 'pulse of the planet,' we must establish a valid end-to-end process that will take us from observations to user-related products. Scientific needs for this end-to-end process require that we … assimilate the Earth observation data streams into models (eventually in real time) …" and "Data assimilation may be the most critical path through which advances in forecasting convective precipitation will be modulated." At its November 16, 2004, meeting, the Interdepartmental Committee for Meteorological Services and Supporting Research (ICMSSR) supported action to examine gaps in data assimilation and data management capability, articulate challenges that lie ahead in meeting future requirements, and propose strategy to address gaps in capability and future challenges. And Action Item 2004-1.2 from the Federal Committee for Meteorological Services and Supporting Research (FCMSSR) December 1, 2004, meeting, recommended that: FCMSSR agencies will support R&D needs and requirements based on agency priorities and will continue to identify issues and concerns that are necessary for the development of capabilities required to realize societal benefits; federal requirements and capabilities in key areas like data assimilation need to be surveyed and further addressed; and FCMSSR agencies will support and facilitate opportunities for the transition of research into operational applications.

The data assimilation survey and follow-on strategy was briefed at the July 18, 2006, ICMSSR meeting. It was noted that the focus of the report which is being prepared is on data assimilation for the purpose of improving forecast skill of a numerical weather prediction (NWP) model; the scope of data assimilation is restricted to incorporation of observational data as a forcing factor in cycles of forward NWP models; and broader definition of data assimilation would be addressed through inclusion of related activities such as climate reanalysis, trace constituent monitoring, and air quality. Key data assimilation issues are:

- Data delivery and standard formatting.
- How best to evolve assimilation techniques over time to meet future application challenges.
- Early delivery of new instrument data.
- Testing and transitioning new data assimilation techniques and concepts into "hardened" data assimilation instruments for operational use.
- Impact of the national shortfall in high performance computing and support for trained personnel on meteorological data assimilation and modeling.
- Data staging and delivery required for Global Earth Observation System of Systems (GEOSS)-level infrastructure capability.
- Education and public outreach: implications for data assimilation and modeling.
- Funding issues.

Data gathering and data assimilation activity analysis tasks are essentially complete; the report framework and key issues have been defined by the data assimilation group; and next steps are being defined. The report, *Federal Meteorological Data Assimilation Capabilities*, will be published in the fall of 2006, and this item will be briefed to FCMSSR around that time.

ENVIRONMENTAL LITERACY

OFCM has laid out a vision, framework, and methodology which the office will embrace to systematically promote and execute environmental literacy through interdepartmental collaboration within the OFCM coordinating infrastructure. The methodology defines how to determine if an opportunity to promote environmental literacy exists. It also describes the method to be used to determine the target public, private, and/or academic sector audiences and how to reach them. Determining the target audiences' needs and a means for assessing how those needs are being met is incorporated into the methodology as well. Executing this methodology will result in a nation better able to understand the linkages between weather and climate and personal and professional choices and build a national capacity to solve problems and respond to change. It will provide for a more environmentally literate citizenry. In this regard, the OFCM developed an implementing strategy/action plan to make environmental literacy a crosscutting priority within the OFCM coordinating infrastructure. *An Implementing Strategy for Promoting Environmental Literacy as an OFCM Crosscutting Priority* was presented to the science community at the American Geophysical

Union (AGU) Fall Meeting, December 5-9, 2005, in San Francisco, California. OFCM is also making environmental literacy an important part of the National Wildland Fire Weather Needs Assessment discussed earlier in this report. OFCM will also continue its support of an American Meteorological Society undergraduate scholarship in the atmospheric and related oceanic and hydrologic sciences.

FREQUENCY MANAGEMENT

Both international and domestic spectrum policy are of critical importance to the federal meteorological community and can significantly impact our ability to carry out our assigned duties and responsibilities. The OFCM Working Group for Frequency (Radio Spectrum) Management (WG/FM) acts as a two-way clearinghouse for information on environmental use of the radio spectrum. It fosters cooperation and coordination among federal agencies for the collection and consolidation of agency needs and requirements related to frequency management issues as they affect meteorological services, and planned non-environmental spectrum uses that may affect the environmental community for good or ill. During the first quarter of FY 2006, OFCM updated its frequency management issues document to provide the interagency community with background information, current status of meteorological uses, potential future technology that could impact spectrum bandwidth, identification of other new frequency management issues, and recommendations for agency involvement in the radio spectrum area. WG/FM met October 28, 2005, at which time the members approved and discussed future updates to the frequency management issues document, and reviewed the Office of Radio Frequency Management (ORFM) role and the NOAA/DOC spectrum plan. A particular issue which has arisen concerns possible interference of radiosonde operations with medical implants within the human body. In May 2006, OFCM placed on its Web site information on this subject for the frequency management community.

GUIDANCE AND PRACTICES FOR XML

The recently formed Committee for Environmental Information Systems and Communications (CEISC) Joint Action Group for Extensible Markup Language and Web Services (JAG/XMLWS) reviewed the members' current Meteorological and Oceanographic (METOC) XML implementations and agreed to use DOD's Joint METOC Broker Language (JMBL) as a starting point for a U.S. position. A *Report on the use of XML within the U.S.* was presented to the Expert Team on Data Representation and Codes (ET/DR&C) at its meeting May 8-12, 2006. ET/DR&C is currently tasked by World Meteorological Organization's (WMO) Commission for Basic Systems (CBS) to develop XML guidance, practices, and any associated WMO standards for the representation and delivery of meteorological information using XML. The ET/DR&C recommended that CBS create a new Expert Team to tackle the XML standardization issue. Assuming that CBS approves the recommendation when they meet in November 2006, the U.S. could then nominate our own experts, perhaps from the JAG/XMLWS to participate in the development of an XML standard.

COLLABORATION WITH NAS/NRC BOARD ON ATMOSPHERIC SCIENCES AND CLIMATE

The OFCM continued its mutually beneficial interactions with the National Academy of Sciences/National Research Council (NAS/NRC). The NAS/NRC Board on Atmospheric Sciences and Climate (BASC) conducted a strategic planning workshop on August 8-9, 2006, in which the Federal Coordinator for Meteorology participated. The workshop was held at the J. Erik Jonsson Woods Hole Center of the National Academy of Sciences in Woods Hole, Massachusetts. The purposes of the meeting were to identify emerging issues facing the atmospheric sciences and climate communities, and to discuss future goals of BASC and set priorities for action. Emerging issues were examined in meteorology, weather, atmospheric composition and other areas relevant to the BASC mission. A balance was achieved in considering issues in basic and applied science, and policy; varied disciplines and interdisciplinary areas; and technology as well as research.

COLLABORATION WITH THE COMMITTEE ON ENVIRONMENT AND NATURAL RESOURCES

CENR PRINCIPALS

The Federal Coordinator continued to be a participant on the CENR, and continued to assist CENR through review and concurrence of CENR reports and materials. Since the last ICMSSR meeting, these included: (1) the U.S. CCSP Synthesis and Assessment Product 1.1, *Temperature Trends in the Lower Atmosphere-Steps for Understanding and Reconciling Differences*, a report by the U.S. CCSP and the CENR Subcommittee on Global Change Research (SGCR), (2) *Grand Challenges for Disaster Reduction Implementation Plans*, authored by the CENR Subcommittee on Disaster Reduction (SDR), (3) United States Group on Earth Observations (USGEO) Annual Report and USGEO Near Term Opportunity Reports, (4) *A Multiyear Research and Program Management Plan for Particulate Matter - a Response to the NRC's Committee on Research Priorities for Airborne*

Particulate Matter's Report IV, and (5) CENR Toxics and Risk Subcommittee Charter.

SUBCOMMITTEE ON DISASTER REDUCTION

The OFCM has been an active participant in the work of the CENR Subcommittee on Disaster Reduction (SDR). SDR has developed Grand Challenges implementation plans, to improve the nation's capacity to prevent and recover from disasters. These disaster scenarios serve as a useful tool for sharing the ideas behind the 2005 SDR Grand Challenges document and demonstrating their possible application. The implementation plans include such topics as assessing disaster resilience, understanding the natural processes that produce hazards, promoting risk-wise behavior, etc. SDR has also completed a Windstorm Impact Reduction Implementation Plan which is the culmination of an SDR-led, coordinated federal effort, in cooperation with other levels of government, academia, and the private sector, to improve understanding of windstorms and their impact, and develop and encourage implementation of cost-effective mitigation measures to reduce those impacts while promoting community resilience. In addition, the SDR working group on satellite issues has participated in the creation of a waiver for the 24-hour wait period on high resolution commercial satellite imagery. The need of state and local governments as well as private entities to respond quickly in the aftermath of Hurricane Katrina and other natural disasters was the impetus behind the waiver request, which has been instituted domestically. OFCM is committed to working with SDR to provide a forum for information sharing, development of collaborative opportunities, and interactive dialogue with the U.S. policy community to advance informed strategies for managing risks associated with natural and technological disasters.

AMERICAN METEOROLOGICAL SOCIETY

During FY 2006, the OFCM joined in supporting the new 2006/2007 American Meteorological Society (AMS) Freshman Undergraduate Scholarship Program. The scholarship program is open to all high school students and designed to encourage study in the atmospheric and related sciences. The scholarships will be awarded, based on academic excellence, to high school seniors entering their freshman year of study in the atmospheric, oceanic, or hydrologic sciences. The scholarships are for the freshman and sophomore years, with second-year funding dependent on successful completion of the first year. The OFCM also supports AMS endeavors by participating in AMS conferences and workshops and other environmental science education and outreach programs, including for example the December 19-21, 2005, policy forum *Building America's Resilience to Hazards* held in Washington, D.C.; and the January 29 - February 2, 2006, 86th AMS Annual Meeting in Atlanta, Georgia, at which OFCM provided a presentation on Weather Information for Surface Transportation (WIST). In addition, an OFCM staff member is Chairperson of the AMS Weather Analysis and Forecasting Committee; Cochair of the 2007 AMS Annual Meeting to be held in San Antonio, Texas; and a member of the AMS Reichelderfer Award Committee.

INTERNATIONAL COLLABORATION

During FY 2005, the Federal Coordinator provided a comprehensive briefing on the OFCM and interagency coordination of federal meteorological activities to Dr. Xu Xiaofeng and a delegation of 25 individuals from the Chinese Meteorological Administration, on May 24, 2005. Then on August 24, 2005, the Federal Coordinator hosted and briefed Dr. Zheng Guoguang, Deputy Administrator of the Chinese Meteorological Administration. Also, news media from Japan attended and conducted interviews at the 59th Interdepartmental Hurricane Conference in Jacksonville, Florida, March 7-11, 2005. OFCM continued to participate in opportunities as they arose during FY 2006. The OFCM Committee for Environmental Information Systems and Communications (CEISC) and its Joint Action Group for XML and Web Services (JAG/XMLWS) prepared a U.S. position paper on the World Meteorological Organization's (WMO) development on guidance and practices for XML based representation and delivery of meteorological information which was presented at the meeting of the Expert Team on Data Representation and Codes (ET/DR&C) in Montreal, Canada, May 8-12, 2006. In the position paper, the U.S. supported the efforts of the ET/DR&C to develop XML guidance, practices, and any associated WMO standards for the representation and delivery of meteorological information; and noted that the U.S. has a substantial body of work to share with the ET/DR&C, and would like to be involved in all steps of the process.

PUBLICATIONS AND OFCM'S WEB SITE

The following publications were prepared in hardcopy form and/or have been placed on OFCM's Web site (www.ofcm.gov):

- *The Federal Plan for Meteorological Services and Supporting Research-Fiscal Year 2006*

- *National Winter Storms Operations Plan*

- *National Hurricane Operations*

Plan

- *Federal Research and Development Needs and Priorities for Phased Array Radar*

- *Report of the Assessment Committee for the National Space Weather Program*

- *Weather Information for Surface Transportation-Update on Weather Impacts and WIST Results*

- *Federal Meteorological Handbook No. 1-Surface Weather Observations and Reports*

- *Federal Meteorological Handbook No. 11-Doppler Radar Meteorological Observations; Part A-System Concepts, Responsibilities and Procedures*

- *Federal Meteorological Handbook No. 11-Doppler Radar Meteorological Observations; Part B-Doppler Radar Theory and Meteorology*

- *Federal Meteorological Handbook No. 11-Doppler Radar Meteorological Observations; Part D-WSR-88D Unit Description and Operational Analysis*

The following documents are planned for publication during FY 2007:

- *The Federal Plan for Meteorological Services and Supporting Research-Fiscal Year 2007*

- *Federal Meteorological Data Assimilation Capabilities*

- *National Hurricane Operations Plan*

- *Interagency Strategic Research Plan for Tropical Cyclones: The Way Ahead*

- *Strategic Plan for Improved Tropical Cyclone Reconnaissance Systems*

- *Criteria for Selection of Joint Urban Test Beds (JUTB)*

- *Federal Meteorological Handbook No. 11-Doppler Radar Meteorological Observations; Part C-WSR-88D Products and Algorithms*

During FY 2006, the OFCM continued to make substantial progress on its use of the Internet. In addition to information about the office, the OFCM has placed its current publications on its Web site, and keeps the Web site current with information regarding workshops and forums being conducted by the office. The OFCM will continue to make information available on the Internet during FY 2007.

Table A.1 Current OFCM Publications

Publication Title	Date	Number
Federal Plan for Meteorological Services and Supporting Research, Fiscal Year 2006	*October 2005*	*FCM-P1-2005*
Urban Meteorology: Meeting Weather Needs in the Urban Community	*January 2004*	*FCM-R22-2004*
National Plan for Space Environment Services and Supporting Research: 1993-1997	August 1993	FCM-P10-1993
National Severe Local Storms Operations Plan	*May 2001*	*FCM-P11-2001*
National Hurricane Operations Plan WSR-88D Tropical Cyclone Operations Plan	*May 2006*	*FCM-P12-2006*
National Winter Storms Operations Plan	*December 2005*	*FCM-P13-2005*
Federal Plan for Cooperative Support and Backup Among Operational Processing Centers	Nov 2002	FCM-P14-2002
National Plan for Stratospheric Monitoring, 1988-1997	July 1989	FCM-P17-1989
National Aircraft Icing Technology Plan	April 1986	FCM-P20-1986
National Plan to Improve Aircraft Icing Forecasts	July 1986	FCM-P21-1986
Federal Plan for the Coordination of Automated Weather Information System Programs	May 1988	FCM-P23-1988
Federal Plan for Meteorological Information Management	July 1991	FCM-P24-1991
National Plan for Tropical Cyclone Research and Reconnaissance (1997-2002)	*January 1997*	*FCM-P25-1997*
National Aviation Weather Program Plan	September 1992	FCM-P27-1992
National Geostationary Operational Environmental Satellite (GOES) Data Collection System (DCS) Operations Plan	August 1997	FCM-P28-1997
Federal Plan for Marine Environmental Data, Services, and Supporting Research	June 1996	FCM-P29-1996
The National Space Weather Program: Strategic Plan	*August 1995*	*FCM-P30-1995*
The National Space Weather Program: Implementation Plan - 2nd Edition	*July 2000*	*FCM-P31-2000*
National Aviation Weather Strategic Plan	*April 1997*	*FCM-P32-1997*
National Post-Storm Data Acquisition Plan	*March 2003*	*FCM-P33-2003*
National Aviation Weather Initiatives	*February 1999*	*FCM-P34-1999*
National Aviation Weather Initiatives, Final Baseline Tier 3 and 4 Report	April 2001	Unnumbered
National Aviation Weather Program/Projects (Tier 3/4 Baseline Update)	December 2003	FCM-R21-2003
Federal Meteorological Handbook No. 1 - Surface Weather Observations and Reports	*September 2005*	*FCM-H1-2005*

Table A.1 Current OFCM Publications (cont.)

Publication Title	Date	Number
Federal Meteorological Handbook No. 2 - Surface Synoptic Codes	December 1988	FCM-H2-1988
Surface Synoptic Code Tables (Update)	July 1990	FCM-T1-1990
Federal Meteorological Handbook No. 3 - Rawinsonde and Pibal Observations	*May 1997*	*FCM-H3-1997*
Federal Meteorological Handbook No. 10 - Meteorological Rocket Observations	December 1988	FCM-H10-1988
Federal Meteorological Handbook No. 11 - Doppler Radar Meteorological Observations		
Part A - System Concepts, Responsibilities and Procedures	*April 2006*	*FCM-H11A-2006*
Part B - Doppler Radar Theory and Meteorology	*December 2005*	*FCM-H11B-2005*
Part C - WSR-88D Products and Algorithms	February 1991	FCM-H11C-1991
Part D - WSR-88D Unit Description and Operational Analysis	*February 2006*	*FCM-H11D-2006*
Federal Meteorological Handbook No. 12 - United States Meteorological Codes and Coding Practices	*December 1998*	*FCM-H12-1998*
Directory of Atmospheric Transport and Diffusion Consequence Assessment Models	*March 1999*	*FCM-I3-1999*
Federal Directory of Mobile Meteorological Equipment and Capabilities	*December 1995*	*FCM-I5-1995*
A Guide to WMO Code Form FM 94 BUFR	*March 1995*	*FCM-I6-1995*
Tropical Cyclone Studies	December 1988	FCM-R11-1988
Tropical Cyclone Studies Supplement	August 1989	FCM-R11-1988S
Interdepartmental Meteorological Data Exchange System Report, IMDES	*August 1998*	*FCM-R12-1998*
Federal Meteorological Requirements 2000	October 1990	FCM-R13-1990
U.S. Wind Profiler: A Review	*March 1998*	*FCM-R14-1998*
Atmospheric Modeling of Releases from Weapons of Mass Destruction	August 2002	FCM-R17-2002
Weather Information for Surface Transportation--National Needs Assessment Report	*December 2002*	*FCM-R18-2002*
Report on Wind Chill Temperature and Extreme Heat Indices: Evaluation and Improvement Projects	*January 2003*	*FCM-R19-2003*
National Aviation Weather Program Mid-Course Assessment	*August 2003*	*FCN-R20-2003*
Standard Formats for Weather Data Exchange Among Automated Weather Information Systems	November 1994	FCM-S2-1994
Standard Telecommunication Procedures for Weather Data Exchange (under revision)	October 1991	FCM-S3-1991
Federal Standard for Siting Meteorological Sensors at Airports	*August 1994*	*FCM-S4-1994*
Proceedings of the Workshop on Multiscale Atmospheric Dispersion Modeling within the Federal Community	*June 2000*	
Proceedings of the Aviation Weather User Forum--Aviation Weather: Opportunities for Implementation	*July 2000*	

Table A.1 Current OFCM Publications (cont.)

Publication Title	Date	Number
Proceedings for the Symposium on Weather Information for Surface Transportation: Delivering Improved Safety and Efficiency for Tomorrow	*February 2000*	
Proceedings of the Symposium on Weather Information for Surface Transportation -- Preparing for the Future: Improved Weather Information for Decision Makers	*March 2001*	
Proceedings of the Forum on Risk Management and Assessment of Natural Hazards	*July 2001*	
Proceedings of the Workshop on Strategy for Providing Atmospheric Information	*March 2002*	
Aviation Weather Training: A Report on Training for Emerging and Recently Implemented Aviation Weather Programs	*April 2002*	*FCM-R16-2002*
Proceedings of the Workshop on Effective Emergency Response	*May 2002*	
Federal Research and Development Needs and Priorities for Atmospheric Transport and Diffusion Modeling	*September 2004*	*FCM-R23-2004*
Aviation Weather Programs/Projects-2004 Update (Tier ¾ Baseline Update)	*December 2004*	*FCM-R21-2004*
Proceedings of the 2nd International Conference on Volcanic Ash and Aviation Safety	*November 2004*	
Proceedings of the User Forum on Urban Meteorology	*March 2005*	
Federal Research and Development Needs and Priorities for Phased Array Radar	*June 2006*	*FCM-R25-2006*
Report of the Assessment Committee for the National Space Weather Program	*June 2006*	*FCM-R24-2006*
Weather Information for Surface Transportation - Update on Weather Impacts and WIST Results	*August 2006*	*FCM-R26-2006*

Italics = publication available online at *www.ofcm.gov*

APPENDIX B

WORLD WEATHER PROGRAM

The Department of Commerce (DOC) was designated by the President, following Senate Concurrent Resolution 67 (1968), to be the lead agency for coordinating United States participation in the World Weather Program (WWP). Until 1983, DOC published a separate report on WWP Plans. Beginning with the 1983 edition of the Federal Plan for Meteorological Services and Supporting Research, a section on the WWP has been included, obviating the need for a separate report. The last segment of this narrative includes information on bilateral and regional international cooperative activities which are not under the WWP.

GOALS AND ORGANIZATION

The World Weather Watch Program (WWWP) is the core of the World Meteorological Organization's (WMO) programs and continues to receive the highest budget priority. The WWWP goals are to extend the time, accuracy, range, and scope of weather prediction and to understand the physical basis of climate and climatic change. The ability of the U.S. and other nations to use their existing scientific capability to understand the climate and to increase their weather predicting skills is limited by the lack of global weather data. Available weather data are inadequately observed over a significant portion of the Earth's surface, especially over isolated areas including the oceans.

Development of the technology and the systems to obtain these observations, especially over the oceans, presents formidable problems. With the use of satellites, aircraft, ships, radar, anchored and drifting buoys, and balloons, however, an integrated system can be developed to observe and collect comprehensive data about the atmosphere over the entire globe. This system is too complex and expensive to be implemented by a single nation--a fact clearly recognized by the leaders of many nations whose international cooperation in meteorology has been a tradition for more than a century. In 1961, this continuing need for international cooperation prompted the President of the United States to propose to the United Nations (UN) the establishment of an international effort in weather prediction. The UN responded by calling upon the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU) to develop measures to improve weather forecasting capabilities and to advance the knowledge of the basic physical forces that determine climate.

The WMO, with 181 member states and 6 member territories, is an intergovernmental organization affiliated with the UN to facilitate international cooperation in the fields of meteorology, climate, and operational hydrology. The WMO responded to the UN request with the concept of the World Weather Watch (WWW), an operational system to bring the global atmosphere under improved surveillance and to provide for the rapid collection and exchange of weather data as well as for the dissemination of weather products from centralized processing centers.

More recently, the WMO is working towards the design and implementation of improved observations for a Global Climate Observing System (GCOS) through enhancements to the Global Observing System (GOS) and other appropriate measures. These efforts are expected to yield an enhanced GOS for both operational and research purposes and are part of the effort to strengthen the WMO's commitment to improve the understanding of climate and related environmental matters, as articulated by the Second World Climate Conference in 1990, and repeated at the UN Conference on the Environment and Development in 1992. The WMO has established the concept of a Regional Basic Climate Network (RBCN); most observing stations would function as part of both the Regional Basic Synoptic Network (RBSN) and the RBCN.

The responsibilities of U.S. Federal agencies in the WWW are as follows:

- Department of Commerce (DOC). Represents the U.S. at WMO and, through the National Oceanic and Atmospheric Administration (NOAA), provides the focal point to coordinate our Nation's efforts in these international programs, implements those service improvements in the existing international weather system for which the U.S. accepts responsibility, and develops new technology. The U.S. is one of three (Russia and Australia are the other two) World Meteorological Centers, which includes World Data Centers and the principal telecommunication gateway for the WMO's Global Telecommunication System (GTS).
- Department of State (DOS). The DOS is the principal source for U.S.-appropriated funds to the WMO. The DOS maintains relations with developing nations and, through NOAA and the WMO, assists developing nations through the Voluntary Cooperation Program (VCP) to improve their national weather services. DOS also develops appropriate multilateral and bilateral arrangements to further international participation.
- National Science Foundation (NSF). The NSF stimulates and supports basic and applied research by scientists primarily in academia on atmospheric and ocean circulation and models. It also promotes the education and training of atmospheric and ocean sci-

entists at universities.

• Department of Defense (DOD). Although the mission of DOD weather services is basically internal, the nature of the DOD's operations is global. As such, the observation, telecommunications, and data-processing programs of the DOD weather services provide significant indirect support to the WWW through DOD's interface with NOAA's National Weather Service (NWS). Information from the research and development activities of these services is exchanged routinely with other similar national agencies and is often presented at national forums. DOD also operates a polar-orbiting meteorological satellite program.

• Department of Transportation (DOT). Through the U.S. Coast Guard, DOT provides personnel to support NOAA's National Data Buoy Center (NDBC) in developing, deploying, operating, and evaluating data buoy systems. DOT's Federal Aviation Administration's terminal aerodrome meteorological observations and air traffic telecommunication network provides an important source of data to the WWW.

• National Aeronautics and Space Administration (NASA). NASA performs research, develops aerospace technology required for an effective global weather system, and provides data from R&D satellites to the WWW. NASA launches for NOAA both polar-orbiting and geostationary satellites.

• Department of the Interior (DOI). DOI's U.S. Geological Survey (USGS) is an important source of hydrologic data used in flood forecasting. The USGS, in addition to its advisory role on water issues in the WMO, will assume a greater functional role in the WMO's emerging water program.

• Department of Agriculture (USDA). USDA is a valuable resource for surface climatological meteorological data from cooperating observers. The department's World Climate Observing Board is responsible for monitoring the impact of climate and extreme weather on both national and international commercial crops. USDA is on the WMO technical commission that works on agrometeorological issues.

THE WORLD WEATHER WATCH (WWW)

The WWW is an integrated member-operated observing system linked by the GTS and it functions on three levels -- global, regional, and national. The WWW is divided into three essential elements that are closely linked and interdependent - the Global Data Processing System (GDPS), Global Telecommunication System (GTS), and the Global Observing System (GOS).

These elements are coordinated and closely integrated through three WWW support functions:

• The data management function coordinates, monitors, and manages the flow of data and products within the WWW system to assure their quality and timely delivery. It also includes the definition and use of code forms for data exchange.

• The systems support activity provides guidance, technical and scientific information, and training to those involved in the planning, development, and operation of WWW components.

• The implementation and coordination function assures the timely completion of the WWW implementation and effective support and maintenance of the WWW system.

GLOBAL OBSERVING SYSTEM (GOS)

The GOS is a coordinated observing system, employing standardized techniques for making meteorological and marine surface observations on a worldwide scale. It is a composite system, containing surface-based (national networks), airborne (civil aviation), and space-based (satellite) subsystems. The main elements of the network and airborne subsystems include:

• The Regional Basic Synoptic Network (RBSN), staffed and automated, for both surface and upper-air observations.

• Fixed observing stations at sea, composed of fixed and anchored platform stations, and island and coastal stations.

• Mobile sea stations, including moving ships.

• Moored and drifting buoys.

• Aircraft meteorological stations, including automated aircraft reporting systems.

ENVIRONMENTAL SATELLITES

NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), manages the U.S. civil operational environmental satellite systems. NESDIS procures, launches, and operates two types of satellites to provide worldwide environmental data and information products and services to Federal agencies, state and local governments, and private users. They are the Polar-orbiting Operational Environmental Satellite (POES) and Geostationary Operational Environmental Satellites (GOES).

Currently NESDIS is operating six polar orbiters. The newest series of POES satellites began with the launch of NOAA-15 in May 1998, followed by NOAA-16 on September 21, 2000, NOAA-17 on June 24, 2002, and finally NOAA-18 on May 20, 2005. NOAA-17 and NOAA-18 are classified as the primary operational satellites. NOAA-12, NOAA-14, NOAA-15, and NOAA-16 satellites continue to transmit data as stand-by satellites. NOAA-17 serves as the primary morning satellite and NOAA-18 the primary afternoon satellite.

The POES satellites are circling the Earth in an almost north-south orbit, passing close to both poles. These orbits have an altitude between 830 km (morning orbit) and 870 km (afternoon orbit) and are sun synchronous. One

satellite crosses the equator in descending orbit at 10:00 AM local time, the other at 2:00 PM local time. Operating as a pair, these satellites ensure that data for any region of the Earth are no more than six hours old. Each satellite orbits the Earth 14 times per day, collecting global data for atmospheric and surface measurements in support of short-term weather forecasting and long-term global climate change research. NOAA also manages the command, control, and communications function of the DOD's Defense Meteorological Satellite Program (DMSP) constellations.

An agreement with the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) gives EUMETSAT responsibility for the morning segment of NOAA's polar environmental mission (circa 9:30 AM LST), with U.S.-provided payload instruments and sensors, beginning in 2006. Upon inception of this operational arrangement, NOAA will operate the afternoon mission while EUMETSAT will support the morning mission. Under this joint mission, upgraded instruments will be flown that will result in improvements for the user community.

NESDIS is also responsible for operating two geostationary satellites, referred to as GOES East and GOES West, plus an on-orbit spare satellite. Each satellite views nearly one third of the Earth's surface. The GOES-12 (East) satellite is positioned at 75 degrees W longitude at the equator and monitors North and South America and most of the Atlantic Ocean. GOES-11 (West) is positioned at 135 degrees W longitude at the equator and monitors North America and the Pacific Ocean basin. These two satellites operate together to provide continuous monitoring necessary for effective and extensive weather forecasting, prediction, and environmental monitoring. GOES East and West are in geosynchronous orbits, which means they orbit the equatorial plane of the Earth at a speed matching the Earth's rotation. This allows them to continuously view one part of the Earth's surface. The geosynchronous orbit is about 35,800 km (22,300 miles) above the Earth's equator. On May 24, 2006, GOES-13 was launched. This spacecraft is the first spacecraft of the GOES N-P series. This new series improves NOAA's coverage during spacecraft eclipse season. After checkout of the satellite, GOES-13 will be available as a replacement for GOES East or West in the event of a failure. With the move of GOES-11 to GOES West (replacing GOES-10), GOES-10 will be repositioned to support South America as part of the Global Earth Observation System of Systems (GEOSS).

AIRBORNE OBSERVATIONS

The WWW has pursued a class of automated airborne reporting systems such as the Automated Meteorological Data and Reporting (AMDAR) systems. Over 3000 aircraft now provide reports of pressure, winds, and temperature during flight. The amount of data from aircraft has increased dramatically during recent years -- from 78,000 reports in 2000 to 190,000 reports in 2006. These systems are making a major contribution to the upper-air component of the GOS in regions where there is little or no radiosonde data.

The U.S. AMDAR program began in the early 1980's as a cooperative effort among ARINC (Aeronautical Radio, Inc.), the NWS, and the FAA. Over 150,000 reports of wind and temperature are sent every day in the Binary Universal Form for Representation of Meteorological Data (BUFR) code. These reports are provided by seven airlines: American, Delta, Federal Express (FedEx), Northwest, Southwest, United, and United Parcel Service (UPS). Global cooperation on AMDAR is facilitated by the WMO AMDAR Panel established in 1998 by a number of WMO members operating or intending to operate AMDAR programs. Australia, Canada, China, EUMETNET/E-AMDAR, Japan, New Zealand, Republic of Korea, Russia, Saudi Arabia, South Africa, and the U.S. have AMDAR programs. A number of new countries have directly indicated interest in the past year in developing AMDAR including Slovenia, the Czech Republic, Malaysia, Kenya, and Mauritius, who have also appointed focal points, and Singapore has recommenced exploring possibilities of using targeted data. Specific information and guidance has been provided to all countries. Additionally, Bulgaria and Croatia have begun exploring the potential of using AMDAR in their own national programs.

In addition to wind and temperature data collection, the U.S. program is expanding the operational parameters collected to also include water vapor and turbulence. Water vapor observations from over 75 aircraft, from two different sensors have been routinely available for assessment since early 2005. A new turbulence algorithm, developed by the National Center for Atmospheric Research (NCAR) derives an objective, aircraft-independent measure of turbulence (eddy dissipation rate (EDR)) from aircraft vertical acceleration. The EDR algorithm is currently installed on 400 United Airlines aircraft, is available through the AirDat TAMDAR sensor, and will be added to several additional Southwest Airlines aircraft in the next year as well. EDR reports are being experimentally ingested into the FAA Graphic Turbulence Guidance (GTG) and as an initialization parameter.

SURFACE-BASED OBSERVATIONS

GOS employs both marine and land surface-based observing systems. Approximately 11,000 stations on land take observations at least once every three hours and often hourly of thermodynamic and wind-field parameters of

the atmosphere. About 4,000 of the world's surface stations comprise the RBSN. Data from these stations are exchanged globally in real time. A subset of these surface stations are used in the Global Climate Observing System (GCOS) Surface Network (GSN). The U.S. operates 87 surface stations as part of the GCOS network. Many countries, including the U.S., have available additional surface data from specialized mesoscale networks, such as Oklahoma's Mesonet, used for research, water management, and transportation needs. The U.S. operates about 73 surface stations on the Antarctic continent. Twenty are U.S. government sponsored of which only 4 report regular observations. The other 53 sites are sponsored through university programs.

The lower atmosphere is vertically profiled using a land-based global array of about 900 upper-air stations which deploy at least once per day a balloon-borne radiosonde capable of providing in-situ measurements of basic state parameters. Approximately 15 specially outfitted commercial ships provide upper-air observations over sparsely instrumented oceanic regions. The NWS operates 92 upper-air stations and supports 15 additional sites in the Caribbean and Pacific. For all U.S. activities (including DOD and other agencies), we have reported to WMO a total of 132 sites. The U.S. has also implemented experimental or quasi-operational networks or single sites of ground-based Doppler radars called wind profilers to provide nearly continuous wind soundings. A network of 32 tropospheric wind profilers is being operated quasi-operationally at 404 MHZ, primarily in the central part of the U.S.

MARINE OBSERVATIONS

Over the oceanic regions, the global observing system relies on ships, moored and drifting buoys, profiling floats, and stationary platforms, in addition to derived data from satellite observations. The Volunteer Observing Ship fleet is comprised of some 5,000 commercial ships. About 900 ships report marine meteorology observations at least 25 times per month. A subset of the volunteer ships routinely deploys expendable bathythermograph probes to measure upper-ocean temperatures to a depth of 750 meters; about 20,000 probes are deployed annually. An array of 1250 surface drifting buoys provides 30,000 sea surface temperature and surface air pressure reports per day. Surface currents are derived by tracking the drifter movements. A network of 375 moored buoys provides about 9000 reports of surface marine observations per day. The moored buoys are located offshore of several maritime nations and also span the tropical Pacific and Atlantic Oceans. Implementation of a tropical Indian Ocean moored array is now underway. The Indian Ocean array is planned to be completed by about 2012. Argo--a global array of profiling floats--provides profiles of ocean temperature and salinity to depths of 2000 meters. Each float reports via satellite once every 10 days. As of October 2006, about 2500 Argo floats were in operation around the globe and it is expected that the array will reach its design goal of 3000 floats by early 2007.

GLOBAL CLIMATE OBSERVING SYSTEM (GCOS)

The U.S. has been involved with GCOS since its inception. NOAA's National Climatic Data Center (NCDC) in Asheville, North Carolina, supports a number of GCOS data management activities and hosts the U.S. GCOS Program Office based in Silver Spring, Maryland [see http://www.ncdc.noaa.gov/oa/usgcos/index.htm]. This support fits in with a proactive process approach for GCOS implementation planning with the goal of obtaining a sustainable and robust GCOS observing network for international atmospheric, oceanographic, and terrestrial climate observing. The U.S. national program has taken a three-tiered approach to fostering the GCOS program. This approach involves providing support:

- Internationally to improve and enhance monitoring stations in developing nations that require assistance as identified by the international GCOS Atmospheric Observations Panel for Climate.
- Regionally for workshops and projects such as those in the Pacific Ocean region for ensuring a robust and sustainable GCOS observing program; and
- On a bilateral basis with nations that have entered into agreements with the U.S. on improving climate observing activities.

Meteorological surface-based networks, utilized for climate purposes, make observations of important climate factors; atmospheric profiles; and pollutant emissions, aerosols, and ozone. These surface-based networks are intended to provide the basic observational set needed to define the status and trends in climate of the world, and also to calibrate and validate satellite-based observations. NOAA's U.S. GCOS Program Office has committed to leading the way, in partnership with the GCOS Secretariat at the WMO, to facilitate improvements in the management and operation of GCOS and GCOS-related networks.

In general, GCOS performance measures used by NOAA in managing its international support are intended to gradually increase the quality and quantity of data from the GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN) over the next several years. The performance measures focus on observing system improvements in developing nations in Africa, South America, and the Pacific Islands. The support for developing nations has primarily been for retrofitting surface and upper-air observing stations that have up-to-now been

silent, but yet are key to global climate monitoring activities. Countries that have received new equipment and expendables over the past three years include: Argentina, Armenia, Congo, Cook Islands, Costa Rica, Ecuador, Ivory Coast, Kenya, Maldives, Namibia, the Philippines, and Zimbabwe. The U.S. State Department has been instrumental in aiding in the establishment of regional GCOS maintenance facilities which have been established in the Pacific and the Caribbean. Another one is being planned for Southern and Eastern Africa in order to further the sustainability of the GCOS network in the developing nations of that region.

Additionally, for the GSN, the performance measure is the percent explained variance in mean annual temperature in the developing world. The long-term goal is 90 percent explained variance with a network of 75 stations. This will be accomplished by deploying new observing stations that meet the same stringent requirements as those in the U.S. Climate Reference Network. For the GUAN, the long-term objective is to increase the percent of GUAN sites in the developing world that meet GCOS reporting requirements (i.e., two soundings per day for 25 days in the month, each sounding with temperature/wind data up to 5 hPa and humidity data up to the tropopause). This will be accomplished by modernizing 75 existing GUAN stations. The long-term goal is to have 90 percent of the GUAN stations in the developing world meeting GCOS requirements. The U.S. GCOS Program, in conjunction with the GCOS Secretariat and other elements in NOAA, is working towards the development of a high-quality GCOS Atmospheric Reference Observations Network (GARON). Finally, support for the chemical constituent portion of GCOS, the Global Atmosphere Watch (GAW) program is part of the integrated GCOS support provided.

GLOBAL DATA PROCESSING AND FORECASTING SYSTEM (GDPFS)

The purpose of GDPFS is to make available all processed information required for both real-time and non-real-time applications. GDPFS provides products and processed information, based on recent advances in atmospheric science, using powerful numerical computer methods. Members have real-time, unrestricted access through the GTS to GDPFS products which allow all countries to benefit from their participation in the WWW.

The GDPFS is organized as a three-level system. It consists of World Meteorological Centers (WMC), Regional/Specialized Meteorological Centers (RSMC), and National Meteorological Centers (NMC). Products of RSMCs can be used by members at the national level for further processing or interpretation to provide assistance or service to users. NMCs carry out GDPFS functions at the national level.

In general, real-time functions of the system involve preprocessing of data to include real-time quality control, analysis, and prognosis, and the derivation of appropriate meteorological parameters. The non-real-time functions include data collection and archival, and additional quality control, storage, and retrieval, to include cataloging observational data and processed information for operational and special applications and for research. WMCs are located in Melbourne, Moscow, and Washington, and they provide guidance products used for general short-, medium-, and long-range weather forecasts on a global scale. Melbourne specializes in forecast products for the Southern Hemisphere.

RSMCs with geographical specialization include Algiers, Beijing, Bracknell, Brazilia, Buenos Aires, Cairo, Dakar, Darwin, Jeddah, Khabarovsk, Melbourne, Miami, Montreal, Moscow, Nairobi, New Delhi, Novosibirsk, Offenbach, Pretoria, Rome, Tashkent, Tokyo, Tunic/Casablanca, Washington and Wellington. RSMCs with specialization for tropical cyclone forecasting are: Miami - Hurricane Center, Nadi - Tropical Cyclone Center, New Delhi - Tropical Cyclone Center, Saint Denis, La ReUnion - Tropical Cyclone Center, Tokyo - western Pacific Typhoon Center, and Honolulu - central Pacific Typhoon Center. The European Center for Medium-Range Weather Forecasts (ECMWF) is an RSMC operated by the European community out of Bracknell, UK. The regional centers at Bracknell, Honolulu, Miami, Montreal, New Delhi, and Tokyo also have dual geographical and activity specialization responsibilities. These centers provide regional products used for short- and medium-range forecasting of small, mesoscale, and large-scale meteorological systems by WMCs. The RSMCs located at Beijing, Bracknell, Melbourne, Montreal, Obninsk, Tokyo, Toulouse, and Washington provide, upon request, atmosphere aerosol and chemical transport model products for environmental emergency responses.

Other WMO-designated specialized centers serve emerging development needs: African Center of Meteorological Applications for Development (ACMAD) - Niamey, Niger; ASEAN Specialized Meteorological Center (ASMC) - Singapore; Drought Monitoring Centers (DMC) - Nairobi, Kenya, and Harare, Zimbabwe; INPE - Sao Paulo, Brazil; National Center for Medium Range Weather Forecasting - New Delhi.

INTERNATIONAL SATELLITE COMMUNICATION SYSTEM (ISCS)

The World Area Forecast System (WAFS) has two centers (Washington and London) which are designated by the International Civil Aviation Organization (ICAO) as World Area Forecast Centers (WAFC). The dissemination of aeronautical information via global satellite broadcast began in 1995, through the International Satellite

Communication System (ISCS). The U.S. provides the links to two of the three satellites specified in the system. The WAFS issue upper-level wind and temperature forecasts with global coverage and forecasts of weather elements defined by ICAO as significant.

The U.S. continues to support ten ISCS/WAFS workstations of the Regional Meteorological Telecommunication Network in the Caribbean and also supports the Caribbean weather website (www.caribweather.net).

GLOBAL TELECOMMUNICATION SYSTEM

The GTS provides communication services for the collection, exchange, and distribution of observational data and processed information among the WMCs, RSMCs, and NMCs of the WWW to meet the member needs for real-time or quasi-real-time exchange of information for both operational and research purposes. The GTS also supports other WMO programs, joint programs with other international organizations, and environmental programs as decided by the WMO and is organized on three levels:

- The Main Telecommunication Network (MTN).
- The Regional Meteorological Telecommunication Networks (RMTN).
- The National Meteorological Telecommunication Networks (NMTN).

The GTS is supported by the telecommunications functions of the WMCs, Regional Telecommunications Hubs (RTH), RSMCs, and NMCs. The MTN links the WMCs at Melbourne, Moscow, and Washington with the RTHs at Algiers; Beijing; Bracknell; Brasilia; Buenos Aires; Cairo; Dakar; Jeddah; Maracay, Venezuela; Nairobi; New Delhi; Norrköping, Sweden; Offenbach; Prague; Rome; Sofia; Tokyo; Toulouse; and Wellington. It ensures the rapid and reliable exchange of observational data and processed information required by the members.

The RMTNs consist of an integrated system of links which interconnects RTHs, NMCs, and RSMCs to WMCs. The RMTNs provide for the collection of observational data and the selective distribution of meteorological information to member nations.

In summary, the GTS enables the NMCs to receive and distribute observational data and meteorological information to meet the requirements of members. Ongoing WWW activities include:

- GTS network redesign, referred to as the WMO Information System (WIS), to take into consideration new technical opportunities, such as Internet-like services.
- Improvement of the capacity of MTN links and inclusion of graphics (e.g., Washington-Brasilia, Washington-Buenos Aires, Washington-Tokyo).
- Upgrade of the GTS in the Indian Ocean Basin to facilitate real-time movement of tsunami and natural hazard warnings.
- Continued implementation of satellite-serviced data collection platforms to enhance the collection of meteorological data from upper-air and surface-observing sites.
- Continued implementation of satellite direct-readout stations that are compatible with polar-orbiting satellites and the weather facsimile (WEFAX) component of the geostationary satellites. Planning is underway for eventual conversion of WEFAX to Low-Rate Information Transmission (LRIT) and Automatic Picture Transmission (APT) to Low Rate Picture Transmission (LRPT) formats with the advent of a new generation of satellites.

VOLUNTARY COOPERATION PROGRAM (VCP)

The WMO Voluntary Cooperation Program (VCP) is a technical cooperation program, managed by the WMO, focused on meeting the needs of member countries to implement WMO scientific and technical programs. The VCP endeavors to complement activities being implemented through national meteorological services and WMO trust-fund arrangements, and through other UN organizations such as United Nations Development Programme (UNDP).

The U.S. participates in the WMO VCP with coordination assistance provided by NOAA's National Weather Service. In 2005, the U.S. contributed nearly $2 million dollars to the VCP to support projects and training which enhance the sciences of meteorology and hydrology. The focus this year was to support the theme "Technical Cooperation for Sustainable Development."

U.S. VCP funds provided assistance to developing countries to help develop and improve their WMO telecommunications infrastructure for tsunami and natural disaster warning networks. Through the NWS' National Centers for Environmental Prediction (NCEP), the U.S. VCP supports weather forecast training for the Americas and the Caribbean countries and climate prediction training for Africa. Additionally, in the Pacific, NCEP provides forecaster training for islanders, and new funding is now dedicated to working with regional associations to enhance communications by upgrading of Low-Rate Users Stations in the Island Developing States to provide access to meteorological satellite images in LRIT format for 17 Pacific Island countries and territories.

The U.S. VCP will also support training programs in the Americas to advance satellite data applications and build capacity as part of the Earth Observations Partnerships of the Americas (EOPA) initiative and support the upcoming move of the GOES-10 satellite to provide more regional coverage.

APPENDIX C
PREVIOUS FEATURE ARTICLES

Year	Edition	Title	Author
2005	FY 2006	Living With Wildland Fire in the Urban Environment	Ms. Mary M. Cairns, OFCM
2004	FY 2005	The Rewards of Managing Weather-Related Risks	Mr. Samuel P. Williamson, OFCM
2003	FY 2004	Weather and The Urban Environment: Meeting The Needs of Urban Communities	Ms. Margaret R. McCalla, OFCM
2002	FY 2003	The Need For Weather Information For Surface Transportation: Keeping The Country Safe and On The Move	Ms. Mary M. Cairns, OFCM
2001	FY 2002	Research to Operations: Bridging the Valley of Death	Mr. Robert Dumont, OFCM
2000	FY 2001	The Legacy of Hurricane Floyd--Inland Flooding and a Massive Evacuation	Mr. Robert Dumont, OFCM
1999	FY 2000	Natural Disaster Reduction--Reducing the Impacts of Natural Hazards	OFCM Staff in collaboration with Dr. William Hooke, OAR, and Ms. Keli Tarp, NOAA Public Affairs
1998	FY 1999	Aviation Weather: Taking A Leadership Role	FAA's Aviation Weather Policy Division (ARW-100) Staff
1997	FY 1998	Owning The Weather--An Army Force Multiplier	Mr. Richard J. Szymber, Army
1996	FY 1997	Space Weather - A New Challenge for Meteorologists	Col Jud Stailey, USAF
1995	FY 1996	The Role of Federal Agencies in International Aviation Meteorology	Mr. Blaine K. Tsugawa, OFCM
1994	FY 1995	Data Continuity in the Climatological Record	Dr. Nathaniel B. Guttman, NCDC Mr. Andrew H. Horvitz, NWS Mr. Arthur L. Booth, NOAA-EOSDIS
1993	FY 1994	Training and Professional Development in the Modernized Weather Services	Mr. Eli Jacks, NWS Mr. LeRoy Spayd, NWS
1992	FY 1993	Mesoscale Meteorology	Mr. Floyd F. Hauth, OFCM
1991	FY 1992	Some Recent Developments in Lightning Mapping Systems	Dr. Donald R. MacGorman, NOAA Dr. Frederick R. Mosher, NOAA Ms. Jan S. Lewis, NOAA

Year	Edition	Title	Author
1990	FY 1991	The Next Generation Weather Radar - A System for Locating and Tracking Severe Weather	Mr. E. Don Sarreals, NEXRAD JSPO
1989	FY 1990	Strategic Plan for the Modernization and Associated Restructuring of the National Weather Service	Verbatim reproduction of a plan required by Congress and submitted by DOC and OMB
1988	FY 1989	Supercomputers for Meteorological Services and Supporting Research	(Source or author unknown)

APPENDIX D
ACRONYMS AND ABBREVIATIONS

3D-VAR	Three Dimensional VARiational (DOD)
4DWX	Four Dimensional Weather (DOD)
AA	Active Army
AAO	Amarillo Area Office (DOE)
AASHTO	American Association of State Highway and Transportation Officials (FHWA)
AAU	Alaskan Aviation Unit (NOAA/NCEP)
AB	Authorization Basis
ABCS	Army Battle Command System (DOD)
ABFM	Airborne Field Mill (NASA)
ABL	Airborne Laser (DOD)
ABLE	Atmospheric Boundary Layer Experiment (DOE)
AC	Active Component (DOD)
AC&A	Atmospheric Chemistry and Aerosols (DOE)
ACARS	ARINC Communication Addressing and Reporting System
ACD	Atmospheric Chemistry Division (DOE)
ACE	Aviation Combat Element (DOD)
ACE-IDS	ASOS Controller Equipment - Information Display System (FAA)
ACIS	Applied Climate Information System (USDA)
ACP	Atmospheric Chemistry Program (DOE)
ACSG	Atmospheric and Climate Sciences Group (DOE)
ADA	Atmospheric Decision Aid (DOD)
ADAPT	Atmospheric Data Assimilation and Parameterization Tool (DOE)
ADAS	AWOS/ASOS Data Acquisition System (FAA)
ADEOS	Advanced Earth Observing System (NASA)
AEC	Atomic Energy Commission (DOE)
AEP	Atmospheric Emergency Preparedness (DOE)
AESS	Allied Environmental Support System (DOD)
AF	Air Force
AFB	Air Force Base
AFCCC	Air Force Combat Climatology Center
AFCWC	Air Force Combat Weather Center
AFFSA	Air Force Flight Standards Agency
AFGS	Aviation Forecast Gridded System
AFJI	Air Force Joint Instruction
AFR	Air Force Reserve
AFRL	Air Force Research Laboratory
AFSOC	Air Force Special Operations Command
AFTAC	Air Force Technical Applications Center
AFW	Air Force Weather
AFWA	Air Force Weather Agency
AFWIN	Air Force Weather Information Network
AFWWS	Air Force Weather Weapon System
AF/XOO	Air Force Director of Operations and Training (DOD)
AF/XO	Air and Space Deputy Chief of Staff for Air and Space Operations (DOD)
AF/XOO-W	Air Force Director of Weather
AGFS	Aviation Gridded Forecast System (FAA)
AGRIMET	A conjunction of the words "agricultural" and "meteorology", is a satellite-based network of automated agricultural weather stations operated and maintained by the U.S. Bureau of Reclamation (DOI)
AHPS	Advanced Hydrologic Prediction Services (NOAA/NWS)
AI	Aircraft Icing (NASA)
AIP	Airport Improvement Program (FAA)
AIRMAP	Atmospheric Investigation Regional Modeling, Analysis, and Prediction (NOAA/OAR)

AIRMoN	Atmospheric Integrated Research Monitoring Network (NOAA/OAR)
AIRS	Atmospheric Infrared Sounder (NASA)
AL	Aeronomy Laboratory (NOAA/OAR)
ALDARS	Automated Lightning Detection and Reporting System (FAA)
ALOHA	Areal Locations of Hazardous Atmospheres (a transport and dispersion code)
ALOO	Albuquerque Operations Office
AMC	Army Materiel Command
AMDAR	Aircraft Meteorological Data Relay (WWP)
AMIS	Automated Meteorological Information System (DOD)
AMPS	Automated Meteorological Profiling System (NASA)
AMOS	Automated Meteorological Observing System (DOD)
AMS	Acquisition Management System (FAA)
	American Meteorological Society
AMSR-E	Advanced Microwave Sounding Radiometer
AMSU	Advanced Microwave Sounding Unit
AMU	Applied Meteorology Unit (NASA)
ANG	Air National Guard (DOD)
ANL	Argonne National Laboratory (DOE)
AOC	Aircraft Operations Center (NOAA)
	Air and Space Operations Center (DOD)
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA/ERL)
AOR	Area of Responsibility (DOD)
AOT	Aerosol Optical Thickness (NOAA/NESDIS)
APGEMS	Air Pollutant Graphical Environmental Monitoring System
APS	Aerosol Polarimetry Sensor (APS)
APT	Automatic Picture Transmission (NOAA/NESDIS)
AQG	Air Quality Group (DOE)
AR	Army Regulation
ARAC	Atmospheric Release Advisory Capability (DOE)
ARCS	Atmospheric Radiation CART Sites (NOAA/OAR)
ARG	Accident Response Group (DOE)
ARGO	Global Array of Profiling Floats (NOAA/OAR)
ARGOS	French Satellite Data Collection System
ARINC	Aeronautical Radio Incorporated
ARL	Army Research Laboratory
	Air Resources Laboratory (NOAA and DOE)
ARM	Atmospheric Radiation Monitoring (DOE)
ARNG	Army National Guard
ARO	Army Research Office
ARS	Agricultural Research Service (USDA)
	Air Traffic System Requirements Service (FAA)
	Atmospheric Research Section (DOE)
ARSPACE	Army Space Command
ARSR	Air Route Surveillance Radar (FAA)
ARSST	Army Space Support Team
ARTCC	Air Route Traffic Control Center (FAA)
ARTYMET	Artillery Meteorological (DOD)
ARW	Aviation Weather Directorate (FAA)
ASCAT	Advanced Scatterometer
ASD	Atmospheric Sciences Division (DOE)
ASDAR	Aircraft to Satellite Data Relay
ASNE MSEA	Air and Space Natural Environment Modeling and Simulation Executive Agent (DOD)
ASOG	Air Support Operations Group (DOD)
ASOS	Automated Surface Observing System
	Air Support Operations Squadron (DOD)
ASP	Atmospheric Science Program (DOE)
ASR	Airport Surveillance Radar (FAA)

ATC	Air Traffic Control (FAA)
ATCCS	Army Tactical Command and Control System
ATD	Atmospheric Turbulence and Diffusion
ATDD	Atmospheric Turbulence and Diffusion Division (NOAA/ARL)
ATEC	Army Test and Evaluation Command
ATG	Atmospheric Technologies Group (DOE)
ATLAS	Autonomous Temperature Line Acquisition System (NOAA/OAR)
ATMS	Advanced Technology Microwave Sounder
ATO	Air Traffic Organization (FAA)
	Air Tasking Order (DOD)
ATOS	Appalachian Tropospheric Ozone Study (NOAA/AOC)
ATWIS	Advanced Transportation Weather Information System (FHWA)
AVHRR	Advanced Very High Resolution Radiometer (NOAA)
AVO	Alaskan Volcano Observatory (DOI/USGS)
AVP	Advanced Vehicle Technologies Program (FTA)
AWARDS	Agricultural Water Resources Decision Support (DOI/BUREC)
AWC	Aviation Weather Center (NOAA/NCEP)
AWIPS	Advanced Weather Interactive Processing System (NOAA)
AWIS	Automated Weather Information System
AWN	Automated Weather Network (DOD)
AWOS	Automated Weather Observing System (FAA)
AWR	Aviation Weather Research (FAA)
AWSS	Aviation Weather Sensor System (FAA)
AWTT	Aviation Weather Technology Transfer (FAA)
BAMP	Breton Aerometric Monitoring Program (DOI)
BASC	Board on Atmospheric Sciences and Climate
BCTP	Battle Command Training Program (DOD)
BE	Battlefield Environment (DOD)
BER	Biological and Environmental Research (DOE)
BFA	Battlefield Functional Areas (DOD)
BIO	Basis for Interim Operations (DOE)
BLM	Bureau of Land Management (DOI)
BMDO	Ballistic Missile Defense Office (DOD)
BNL	Brookhaven National Laboratory (DOE)
BUFR	Binary Universal Form for the Representation of Meteorological Data
BUREC	Bureau of Reclamation (DOI)
C^2	Command and Control (DOD)
C^4I	Command, Control, Communications, Computers, and Intelligence (DOD)
CAAM	Computer Assisted Artillery Meteorology (DOD)
CAC	Combined Arms Center (DOD)
CAIB	Columbia Accident Investigation Board
CALJET	California Land-falling Jets Experiment (NOAA/OAR)
CAMEO	Computer Aided Management of Emergency Operations
CAMEX	Convective and Moisture Experiment (NASA)
CAO	Carlsbad Area Office
CAP	Civil Air Patrol
CAP88-PC	Clean Air Act Assessment Package-1988 - Personal Computer (DOE)
CAPARS	Computer-Assisted Protective Action Recommendation System (DOE)
CARDS	Comprehensive Aerological Reference Data Set (NOAA/NCDC)
CARS	Condition Acquisition and Reporting System (FHWA)
CART	Clouds and Radiation Testbed (DOE)
CASPER	Computer Aided System For Planning Efficient Routes (FHWA)
CAST	Commercial Aviation Safety Team (FAA)
CAT	Clear Air Turbulence
CAWIS	Committee for Automated Weather Information Systems (OFCM)

CBIRF	Chemical Biological Incident Response Force (DOD)
CBAP	*Catastrophic Backup Action Plan*
CBNP	Chemical Biological Non-Proliferation Program (DOE) Chemical Biological National Security Program (DOE)
CBOFS	Chesapeake Bay Oceanographic Forecasting System (NOAA/NOS)
CBRNE	Chemical, Biological, Radiological, Nuclear, or High-Yield Explosive (DOD)
CBS	Commission on Basic Services (WWP)
CCAFS	Cape Canaveral Air Force Station
CCCM	Climate and Carbon Cycle Modeling (DOE)
CCM3	Community Climate Model-3 used at LANL (DOE)
CCMC	Community Coordinated Modeling Center (DOD)
CCMS	Committee on the Challenges of Modern Society (EPA)
CDA	Command and Data Acquisition
CDF	Cloud Depiction and Forecasting (DOD)
CDFS	Cloud Depiction and Forecast System (DOD)
CDPHE	Colorado Department of Public Health and Environment (DOE)
CECOM	Communications and Electronics Command (DOD)
CEMSCS	Central Environmental Satellite Computer System (NOAA/NESDIS)
CENR	Committee on Environment and Natural Resources
CEOS	Committee on Earth Observation Satellites (NOAA/NESDIS)
CERES	Clouds and Earth's Radiant Energy System (NASA)
CFD	Computational Fluid Dynamics
CFIT	Controlled Flight Into Terrain (NASA)
CFR	Code of Federal Regulations (DOE)
CGSC	Command and General Staff College (DOD)
CHAMMP	Computer Hardware Advanced Mathematics and Model Physics (DOE)
CHARM	An Atmospheric Transport and Dispersion Model
CIASTA	Cooperative Institute for Atmospheric Studies and Terrestrial Applications (NOAA/OAR)
CICE	Sea Ice Code at LANL
CIDE	Communications Interfaces and Data Exchange (OFCM)
CIOS	Committee for Integrated Observing Systems (OFCM)
CIRES	Cooperative Institute for Research in Environmental Sciences
CIWS	Corridor Integrated Weather System (FAA)
CLASS	Comprehensive Large Array-Data Stewardship System (NOAA/NESDIS)
CLIVAR-GEWEX	Climate Variability and Predictability - Global Energy and Water Cycle Experiment
CLIVAR-VAMOS	Climate Variability and Predictability - Variability and Predictability of the American Monsoon System
C-MAN	Coastal-Marine Automated Network
CMAQ	Community Multi-scale Air Quality (EPA)
CMDL	Climate Monitoring and Diagnostics Laboratory (NOAA/OAR)
CME	Coronal Mass Ejection
CMFC	Coordinating METOC Forecast Center (DOD)
CMIS	Conical Scanning Microwave Imager Sounder
COADS	Comprehensive Ocean-Atmosphere Data Set (NOAA/NCDC)
COAMPS	Coupled Ocean-Atmosphere Mesoscale Prediction System
COARE	Coupled Ocean-Atmosphere Response Experiment
COE	Corps of Engineers (DOD)
COMET	Cooperative Program for Operational Meteorology, Education and Training
CONUS	Continental United States (DOD)
CONUSA	Continental United States Armies (DOD)
COPC	Committee for Operational Processing Centers (OFCM)
COOP	Cooperative Observer Program (NOAA/NWS)
CORMS	Continuous Real-time Monitoring System (NOAA/NOS)
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate (DOD)
COTS	Commercial Off-the-Shelf
CPC	Climate Prediction Center (NOAA/NCEP)
CPHC	Central Pacific Hurricane Center (NOAA/NCEP)

CRADA	Cooperative Research and Development Agreement
CrIS	Cross-track Infrared Sounder
CRN	Climate Reference Network (NOAA)
CRREL	Cold Regions Research and Engineering Laboratory (DOD)
CS	Climate Services
CSD	Climate Services Division (NOAA/NWS)
CSEPP	Chemical Stockpile Emergency Preparedness Program (DOE)
CSRA	Central Savannah River Area (DOE)
CSREES	Cooperative State Research, Education, and Extension Service (USDA)
CSW	Committee for Space Weather (OFCM)
CTA	Common Table of Allowances (DOD)
CTBT	Comprehensive Test Ban Treaty (DOE)
CWS	Combat Weather Squadron (DOD)
CWSU	Center Weather Service Unit (FAA)
CWT	Combat Weather Team (DOD)
CXD	Combined X-ray Dosimeter (DOE)
CY	Calendar Year
DAC	Data Assembly Center (NOAA/OAR)
DAMPS	Distributed Atmospheric Modeling Prediction System (DOD)
DAT	Department of Advanced Technology (DOE)
DCO	Data Collection Office (NOAA/NWS)
DCP	Data Collection Package
	Data Collection Platform (DOI)
DCS	Data Collection System (NOAA/NESDIS)
DEPSCoR	Experimental Program to Stimulate Competitive Research (DOD)
DGPS	Differential Global Positioning System (USGS)
DHS	Department of Homeland Security
DIS	Decision and Information Sciences (DOE)
DISS	Digital Ionospheric Sounding System (DOD)
DMCC	DOE Meteorological Coordinating Council (DOE)
DMS	Dynamic Message Sign (FHWA)
DMSO	Defense Modeling and Simulation Office (DOD)
DMSP	Defense Meteorological Satellite Program (DOD)
DNT	Dinitrotoluene (DOE)
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOMSAT	Domestic Communications Satellite (DOI)
DOS	Department of State
DOT	Department of Transportation
DRA	Desert Rock Meteorological Observatory at NTS (DOE)
DREC	Delta Research Extension Center (USDA)
DRGS	Direct Readout Ground Stations (DOI)
DRI	Desert Research Institute (DOE)
DRWP	Doppler Radar Wind Profiler (NASA)
DTC	Developmental Test Command (DOD)
DTED	Digital Terrain Elevation Data (DOD)
DTRA	Defense Threat Reduction Agency
DTSS	Digital Topographic Support System (DOD)
DUAT	Direct User Access Terminal (FAA)
DURIP	Defense University Research Instrumentation Program (DOD)
EAC	Echelon Above Corps (DOD)
EAD	Environmental Assessment Division (DOE)
EBID	Environmental Biology and Instrumentation Division (DOE)

ECDIS	Electronic Chart Display Information System (NOAA/NOS)
ECMWF	European Centre for Medium-Range Weather Forecasting
EDAS	Eta Data Assimilation System (NOAA/NESDIS)
EDIS	Environmental Data and Information Service (NOAA)
EERE	Office of Energy Efficiency and Renewable Energy (DOE)
ELV	Expendable Launch Vehicle (NASA)
EM	Office of Environmental Management (DOE)
EMC	Environmental Modeling Center (NOAA/NCEP)
	European Modeling Center (NOAA/NCEP)
EMP	Environmental Meteorology Program (DOE)
EMS	Environmental Monitoring Section (DOE)
ENSO	El Niño-Southern Oscillation
EO	Electro-optical
	Earth Observation (NASA)
EOC	Emergency Operations Center
EOS	Earth Observing System (NASA)
EOSDIS	EOS Data and Information System (NASA)
EPA	Environmental Protection Agency
EPD	Environmental Protection Department (DOE)
EPIC	Equatorial Pacific Investigation of Climate (NOAA/AOC)
EPR	Emergency Preparedness and Response Directorate (FEMA)
E-PIREPS	Electronic Pilot Reports (FAA)
EP/RD	Environmental Protection/Restoration Department (DOE)
EPZ	Emergency Planning Zone (DOE)
ER	Eastern Range (NASA)
	Environmental Research (DOE)
ERBS	Earth Radiation Budget Satellite (NASA)
ERC	Extended Research Checkout
ERDA	Energy Research and Development Administration (DOE)
ERDAS	Eastern Range Dispersion Assessment System (NASA)
ERDC	Engineering Research and Development Center (DOD)
ERL	Environmental Research Laboratories (NOAA)
ESD/IPC	Environmental Satellite Distribution/Interactive Processing Center (NOAA/NESDIS)
ESE	Earth Science Enterprise (NASA)
ESP	Energy Spectrometer for Particles (DOE)
	Ensemble Streamflow Prediction (NWS)
ESS	Environmental Sensor Station (FHWA)
ESSP	Earth System Science Pathfinders (NASA)
ETIS	Evacuation Traffic Information System (FHWA)
ETL	Environmental Technology Laboratory (NOAA/OAR)
ETOS	East Tennessee Ozone Study (NOAA/OAR)
ETTP	East Tennessee Technology Park (DOE)
ET Toolbox	Evapotranspiration Toolbox (DOI)
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
EUSA	Eighth U.S. Army
EUV	Extreme Ultraviolet
EWR	Ellason Weather Radar (DOD)
FAA	Federal Aviation Administration
FALOP	Forward Area Limited Observing Program (DOD)
FAS	Foreign Agricultural Service (USDA)
FBA	Fire Behavior Analysts (DOI)
FCC	Federal Communications Commission
FCCC	Framework Convention on Climate Change (DOS)
FCMSSR	Federal Committee for Meteorological Services and Supporting Research (OFCM)
FCS	Future Combat System (DOD)
FDD	First Digitized Division (DOD)

FDIC	Force Development and Integration Center (DOD)
FEM3MP	LLNL finite element model (DOE)
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FIRETEC	Fire Code at LANL (DOE)
FIRST	FAA Icing Remote Sensor Testbed (NOAA/OAR)
FIS	Flight Information System (FAA)
FITL	Forecaster-in-the-Loop (DOD)
FLENUMMETOCCEN	Fleet Numerical Meteorology and Oceanography Center, Monterey, California
FMF	Fleet Marine Force
FMH	Federal Meteorological Handbook (OFCM)
FNMOC	Fleet Numerical Meteorology and Oceanography Center (DOD)
FOA	Field Operating Agency (DOD)
FORSCOM	U.S. Army Forces Command
FOV	Field of vision
FR	Flight Rules
FRA	Federal Railroad Administration
FRD	Field Research Division (NOAA/ARL)
FRERP	Federal Radiological Emergency Response Plan (DOE)
FRMAC	Federal Radiological Monitoring and Assessment Center (DOE)
FRWS	Fire RAWS (DOI)
FS-21	Forecasting System 21st Century (DOD)
FS	Forest Service (USDA)
FSA	Farm Services Agency (USDA)
FSL	Forecast Systems Laboratory (NOAA/OAR)
FSR	Forest Service Research (USDA)
FTA	Federal Transit Administration
FTE	Full-time Equivalent
FTP	File Transfer Protocol
FU	Forecast Unit
FWS	Fish and Wildlife Service (DOI)
FY	Fiscal year
G-IV	Gulfstream IV (NOAA)
GAA	GOES Active Archive (NOAA/NESDIS)
GAC	Global Area Coverage
GACC	Geographic Areas Coordination Center (DOI)
GACP	Global Aerosol Climatology Project (NASA)
GAIM	Global Assimilation of Ionospheric Measurements (DOD)
GAPP	GEWEX Applications Prediction Program (DOI/BUREC)
GAO	General Accounting Office
GCCR	Global Climate Change Research (DOE)
GCCS	Global Command and Control System (DOD)
GCIP	GEWEX Continental-scale International Project (DOI)
GCM	Global Climate Models (DOE)
GCOS	Global Climate Observing System (WWP)
GCPS	Global Climate Perspectives System
GCRP	Global Change Research Program
GDPC	Global Data Processing Centers (WWP)
GDPFS	Global Data Processing and Forecast System (WWP)
GEM	Generation of weather Elements for Multiple (USDA)
GEOSAR	Geostationary Earth Orbit Search and Rescue (NOAA/NESDIS)
GEOSS	Global Earth Observation Systems of Systems (WWP)
GEWEX	Global Energy and Water-Balance Experiment
GFDL	Geophysical Fluid Dynamics Laboratory (NOAA/ERL)
GHCN	Global Historical Climatology Network
G-IPPA	Government-Industry Project Performance Agreement (FAA)
GIN	Geomagnetic Information Nodes (DOI)

GIS	Geographic Information System
GLD	Global Lagrangian Drifters (NOAA/OAR)
GLOFS	Great Lakes Operational Forecast System
GLONASS	Global Navigation Satellite System (NOAA/NESDIS)
GMS	Geostationary Meteorological Satellite-Japan (WWP)
GMSRA	GOES Multi-Spectral Rainfall Algorithms (NOAA/NESDIS)
GMU	George Mason University
GOES	Geostationary Operational Environmental Satellite (NOAA)
GOOS	Global Ocean Observing System
GOS	Global Observing System (WWP)
GOSSP	Global Observing Systems Space Panel (NOAA/NESDIS)
GPCP	Global Precipitation Climatology Program
GPS	Global Positioning System
GPS/MET	GPS for Meteorology
GRIB	Gridded Binary (FM 92-X Ext.)
GRIDS	Ground-based Remote Icing Detection System (NOAA/OAR)
GSFC	Goddard Space Flight Center (NASA)
GSN	GCOS Surface Network (WWP)
GTS	Global Telecommunications System (WWP)
GTSPP	Global Temperature-Salinity Profile Project
GTWAPS	Global Theater Weather Analysis and Prediction System (DOD)
GUAN	GCOS Upper Air Network (WWP)
HAF	Headquarters Air Force (DOD)
HaL	Hurricanes at Landfall (NOAA/OAR)
HAR	Highway Advisory Radio (FHWA)
HARM	Hazardous Atmospheric Release Model (NOAA/OAR)
HAZMET	Hazardous Material (FHWA)
HCRS	Highway Closure and Restriction System (FHWA)
HDB	Hydrologic DataBase (DOI)
HELSTF	High Energy Laser System Test Facility (DOD)
HF	High Frequency
HFRB	High Frequency Regional Broadcast
HIGRAD	Transport and Dispersion Model at LANL (DOE)
HIRS/3	High Resolution Infrared Radiation Sounder (NOAA/NESDIS)
HMI	Hydrologic Modeling Inventory (DOI)
HMSC	Hazardous Materials Spill Center (DOE)
HMMWV	High Mobility Multi-purpose Wheeled Vehicle (DOD)
HPC	Hydrometeorological Prediction Center (NOAA/NCEP)
HPCC	High Performance Computing and Communications
HRAP	Hydrologic Rainfall Analysis Project (DOI)
HRD	Hurricane Research Division (NOAA/ERL)
HRPT	High Resolution Picture Transmission (NOAA/NESDIS)
HSA	Hydrologic Service Area (NOAA/NWS)
HSM	Heat Stress Monitor (DOD)
HYDROMET	A network of automated hydrologic and meteorologic monitoring stations located throughout the Pacific Northwest (DOI)
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectory (NOAA/OAR)
HUD	Head-up display (NASA)
IA	Interagency Agreement
IAMS	Initial Attack Management System (DOI)
IAS	International Airspace System (NOAA/NWS)
IAV	Interim Armored Vehicle (DOD)
IBCT	Interim Brigade Combat Teams (DOD)
ICAO	International Civil Aviation Organization
LCC	Launch Commit Criteria

ICMSSR	Interdepartmental Committee for Meteorological Services and Supporting Research (OFCM)
ICSU	International Council of Scientific Unions
IDCS	International Data Collection System (WWP)
IEW	Intelligence and Electronic Warfare (DOD)
IFEX	Intensity Forecast Experiment
IFFA	Interactive Flash Flood Analyzer (NOAA/NESDIS)
IGBP	International Geosphere Biosphere Programme (WWP)
IHC	Interdepartmental Hurricane Conference (OFCM)
IIP	International Ice Patrol (USCG)
IMA	Individual Mobilization Augmentee (DOD)
IMAAC	Interagency Modeling and Atmospheric Assessment Center
IMDES	Interdepartmental Meteorological Data Exchange System
IMETS	Integrated Meteorological System (DOD)
	Incident Meteorologists (NOAA/NWS)
IMPROVE	Interagency Monitoring of Protected Visual Environments (DOI)
INEEL	Idaho National Engineering and Environmental Laboratory (DOE)
INSAT	India's National Satellite (WWP)
IOC	Intergovernmental Oceanographic Commission (WWP)
IPB	Intelligence Preparation of the Battlespace (DOD)
IPCC	Intergovernmental Panel on Climate Change (WWP/DOS)
IPEX	Intermountain Precipitation Experiment (NOAA/OAR)
IPO	Integrated Program Office
IR	Infrared
IRTSS	Infrared Target Scene Simulation Software (DOD)
ISCCP	International Satellite Cloud Climatology Program (NOAA/NESDIS)
ISES	International Space Environment Service (NOAA/OAR)
ISIS	Integrated Solar Irradiance Study (NOAA/OAR)
ISMS	Integrated Safety Management System (DOE)
ISS	International Space Station
ISTEA	Intermodal Surface Transportation Efficiency Act (FHWA)
IT	Information Technology
ITCT	Intercontinental Transport and Chemical Transformation (NOAA/OAR)
ITCZ	Inter-tropical convergence zone
ITS	Intelligent Transportation System (FHWA)
ITS-JPO	ITS Joint Program Office (FHWA)
IT-RD	Information Technology Research and Development (EPA)
ITWS	Integrated Terminal Weather System (FAA)
IWEDA	Integrated Weather Effects Decision Aid (DOD)
IWGCCST	Interagency Working Group on Climate Change Science and Technology (DOS)
IWRS	Improved Weather Reconnaissance System (OFCM)
IWRPC	Improved Weather Reconnaissance System Program Council (OFCM)
JAAWIN	Joint Air Force-Army Weather Information Network (DOD)
JAG	Joint Action Group
JAG/OCM	Joint Action Group for Operational Community Modeling
JASL	Joint Archive for Sea Level
JAWF	Joint Agricultural Weather Facility (USDA)
JCOMM	Joint Commission for Oceanographic and Marine Meteorology (WWP)
JCS	Joint Chiefs of Staff (DOD)
JCSDA	Joint Center for Satellite Data Assimilation (NOAA/NCEP)
JET	Joint Environmental Toolkit (DOD)
JGOFS	Joint Global Ocean Flux Study
JHT	Joint Hurricane Testbed (NOAA/OAR)
JMDB	Joint METOC Database (DOD)
JMFU	Joint METOC Forecast Unit (DOD)
JMIB	Joint METOC Interoperability Board (DOD)
JMIST	Joint METSAT Imagery, Software, and Terminals (DOD)

JMV	Joint METOC Viewer (DOD)
JPL	Jet Propulsion Laboratory (NASA)
JSAT	Joint Safety Analysis Team (FAA)
JSIT	Joint Safety Implementation Team (FAA)
JSC	Johnson Space Center (NASA)
JSCP	Joint Strategic Capabilities Plan (DOD)
JTWC	Joint Typhoon Warning Center (DOD)
JWIS	Joint Weather Impacts System (DOD)
KAO	Kirtland Area Office
KLC	Kodiak Launch Center (NASA)
KM	Kilometer
KSC	Kennedy Space Center (NASA)
KVERT	Kamchatka Volcanic Eruption Response Team (DOI)
LAAS	Local Area Augmentation System (FAA)
LAC	Local Area Coverage
LAN	Local Area Network
LANL	Los Alamos National Laboratory (DOE)
LAPS	Local Analysis and Prediction System (NOAA/FSL)
LDAR	Lightning Detection and Ranging
LDCM	Landsat Data Continuity Mission (NASA)
LDIS	Local Data Integration System (NASA)
LEO	Low Earth Orbit
LLCC	Lightning Launch Commit Criteria (NASA)
LLNL	Lawrence Livermore National Laboratory (DOE)
LLWAS	Low Level Wind Shear Alert System (FAA)
LLWAS-RS	LLWAS-Relocation/Sustainment (FAA)
LODI	Transport and Dispersion Model at LLNL (DOE)
LRGS	Local Readout Ground Stations (DOI)
LSD	Laboratory Services Division
LSM	Land Surface Model (DOD)
LV	Launch Vehicle
LWS	Living With A Star (NASA)
M2M	Machine-to-Machine
MACOM	Major Army Command
MAGTF	Marine Air Ground Task Force
MAJCOM	Major Command (DOD)
MAW	Marine Aircraft Wing
MB	Millibars
MC	Meteorological Codes
MCAF	Marine Corps Air Facilities
MCAS	Marine Corps Air Station
MCCDC	Marine Corps Combat Development Command (DOD)
MCD	Mesoscale Discussions (NOAA/NWS)
MCO	Maintenance and Construction Operations (FHWA)
MCS	Mesoscale Convective System (NOAA/OAR)
MCSP	Meteorological and Climate Services Project
MCWP	Marine Corps Warfighting Publication (DOD)
MDIFF	Transport and Dispersion Code at INEEL (DOE)
MDCRS	Meteorological Data Communications and Reporting System (WWP)
MDSS	Maintenance Decision Support System (FHWA)
MeaPRS	MCS Electrification and Polarimetric Radar Study (NOAA/OAR)
MEDA	Meteorological Data System
MEF	Mission Execution Forecast (DOD)
MEPED	Medium Energy Proton and Electron Detector (NOAA/NESDIS)

MES	Marine Environmental Services (OFCM)
MET	Mobile Environmental Teams (DOD)
	Meteorological Teams (DOD)
METMF	Meteorological Mobile Facility (DOD)
METOC	Meteorological and Oceanographic (DOD)
METSAT	Meteorological Satellite
MHS	Microwave Humidity Sounder (NOAA/NESDIS)
MHz	Megahertz
MIMS	Multimedia Integrated Modeling System (EPA)
MM5	Mesoscale Meteorological Model-Version 5.0 (DOD)
MME	Mobile Meteorological Equipment (OFCM)
MMS	Meteorological Measuring System (DOD)
	Mineral Management Service (DOI)
	Modular Modeling System (DOI)
MMS-P	Meteorological Measuring System-Profiler (DOD)
MOA	Memorandum of Agreement
MOBY	Marine Optical Buoy (NOAA/NESDIS)
MOCE	Marine Optical Characterization Experiment (NOAA/NESDIS)
MODIS	Moderate Resolution Imaging Spectrometer (NASA)
MOS	Model Output Statistics
MP	Mission Planning (DOD)
MPA	Magnetospheric Plasma Analyzer (DOE)
MPC	Marine Prediction Center (NOAA/NCEP)
MS	Monitoring the Stratosphere (OFCM)
MSFC	Marshall Space Flight Center (NASA)
MSL	Mean Sea Level
MSS	Meteorological Sounding System (NASA)
MST	Meteorological Support Teams (DOD)
MSU	Microwave Sounding Unit (NOAA/NESDIS)
MTN	Main Telecommunications Network (WWP)
MTOE	Modified Table of Organization and Equipment (DOD)
MTPE	Mission to Planet Earth (NASA)
MTSAT	Multi-functional Transport Satellite
MWSS	Marine Wing Support Squadron
MW	Microwave
N511	National 511-Traveler Information Service (FHWA)
NADIN	National Airspace Data Interchange Network (FAA)
NAF	Numbered Air Force
NAME	North American Monsoon Experiment
NAMIS	NATO Automated Meteorological Information System (DOD)
NMAO	NOAA Marine and Aviation Operations
NAP	Non-insured Crop Disaster Assistance Program (USDA)
NAPP	National Aerial Photography Program (USDA)
NAOS	North American Atmospheric Observing System (NOAA)
NARAC	National Atmospheric Release Advisory Center (DOE)
NARSTO	North American Research Strategy for Tropospheric Ozone (EPA)
NAS	National Airspace System (FAA)
	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NASS	National Agricultural Statistics Service (USDA)
NATCOM	National Communications Center (FAA)
NATO	North Atlantic Treaty Organization (DOD, EPA)
NAVICECEN	Naval Ice Center
NAVOCEANO	Naval Oceanographic Office
NAVLANTMETOCCEN	Naval Atlantic Meteorology and Oceanography Center, Norfolk, Virginia

NAVMETOCCOM	Naval Meteorology and Oceanography Command
NAVPACMETOCCEN	Naval Pacific Meteorology and Oceanography Center, Pearl Harbor, Hawaii
NAWPC	National Aviation Weather Program Council (OFCM)
NBC	Nuclear, Biological, and Chemical (DOD)
NC	NOAA Corps
NCA	National Command Authority (DOD)
NCAR	National Center for Atmospheric Research
NCAS	NOAA Center for Atmospheric Sciences
NCDC	National Climatic Data Center (NOAA/NESDIS)
NCEP	National Centers for Environmental Prediction (NOAA/NWS)
NCO	NCEP Central Operations (NOAA/NCEP)
	Non-commissioned officer (DOD)
NDBC	National Data Buoy Center (NOAA/NWS)
NDGPS	Nationwide Differiental Global Positioning System
NDI	Non-developmental item
NDOP	National Digital Orthoquad Program (USDA)
NDRI	Natural Disaster Reduction Initiative (NOAA)
NDVI	Normalized Difference Vegetation Index (NOAA/NESDIS)
NEAQS	New England Air Quality Study
NEPA	National Environmental Policy Act
NERON	NOAA's Environmental Real-Time Observation Network
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA)
NESHAP	*National Emission Standards for Hazardous Air Pollutants* (DOE)
NESS	National Environmental Satellite Service (NOAA)
NEST	Nuclear Emergency Search Team (DOE)
NETRAD	Networked Radars
NEXRAD	Next Generation Weather Radar (WSR-88D)
NFIP	National Flood Insurance Program (FEMA)
NFDRS	National Fire Danger Rating System (DOI/BLM)
NGDC	National Geophysical Data Center (NOAA/NESDIS)
NGIC	National Geomagnetic Information Center (DOI)
NGST	Northrup Grumman Space Technology
NHC	National Hurricane Center (NOAA/NCEP)
NHI	National Highway Institute (FHWA)
NHOP	National Hurricane Operations Plan (OFCM)
NIC	National Ice Center (DOT/USCG)
	National Intelligence Community (DOD)
NIFC	National Interagency Fire Center (DOI)
NIPRNET	Non-secure Internet Protocol Router Network (DOD)
NIRT	Nuclear Incident Response Team
NIST	National Institute of Standards and Technology (DOC)
NITES	Navy Integrated Tactical Environmental Subsystem
NLDN	National Lightning Detection Network (FAA)
NMC	National Meteorological Center(s) (WWP)
NMHS	National Meteorological and Hydrological Services (WWP)
NMOC	Naval Meteorology and Oceanography Command
NMP	New Millennium Program (NASA)
NMS	National Military Strategy (DOD)
NMTN	National Meteorological Telecommunications Network (WWP)
NNDC	NOAA National Data Center (NOAA/NESDIS)
NNSA	National Nuclear Security Administration (DOE)
NNSA/NSO	National Nuclear Security Administration/Nevada Site Office (DOE)
NOAA	National Oceanic and Atmospheric Administration
NOCMP	National Operational Coastal Modeling Program
NODC	National Oceanographic Data Center (NOAA/NESDIS)
NODDS	Navy Oceanographic Data Distribution System
NOGAPS	Navy Operational Global Atmospheric Prediction System

NOHRSC	National Operational Hydrologic Remote Sensing Center
NOS	National Ocean Service (NOAA)
NOTAMS	Notices to Airmen (FAA)
NOWS	NVG Operations Weather Software (DOD)
NPDES	National Pollutant Discharge Elimination System (DOE)
NPN	NOAA Profiler Network (NOAA/OAR)
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Program (NASA)
NPS	National Park Service (DOI)
NRC	Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service (USDA)
NRI	National Research Initiative (USDA)
NRL	Naval Research Laboratory
NRO	National Reconnaissance Office (DOD)
NRVR	New Generation Runway Visual Range (FAA)
NSC	National Security Complex
NSF	National Science Foundation
NSIDC	National Snow and Ice Data Center (NOAA)
NSO	Nevada Site Office (DOE)
NSS	National Security Strategy (DOD)
NSSL	National Severe Storms Laboratory (NOAA)
NSTC	National Science and Technology Council
NSTEP	National Strategic Training and Education Plan (NOAA/NWS)
NSWP	National Space Weather Program (OFCM)
NTCIP	National Transportation Communications for ITS Protocol (FHWA)
N-TFS	New Tactical Forecast System (DOD)
NTIS	National Technical Information Service
NTS	Nevada Test Site (DOE)
NTSB	National Transportation Safety Board
NV	Nevada Operations Office (DOE)
NVG	Night vision goggles (DOD)
NWA	National Wilderness Area (DOI)
NWCC	National Water & Climate Center (USDA)
NWCG	National Wildfire Coordinating Group (USDA)
NWIS	National Water Information System (DOI)
NWLON	National Water-Level Observation Network (NOAA/NOS)
NWP	Numerical Weather Prediction
NWS	National Weather Service
NWSRFS	National Weather Service River Forecast Service (NOAA/NWS)
NWSTC	National Weather Service Training Center (NOAA/NWS)
NXDP	National Xeriscape Demonstration Program (DOI)
O&C	Oregon and California Railroad Land Grants (DOI)
OAR	Office of Oceanic and Atmospheric Research (NOAA)
OASIS	Operational and Supportability Implementation System (FAA)
OB	Operational Build
OCAP	Operating Consortium of ASDAR Participants (WWP)
OCE	Office of the Chief Economist (USDA)
OCRWM	Office of Civilian Radioactive Waste Management
OCWWS	Office of Climate, Water, and Weather Services (NOAA/NWS)
OFCM	Office of the Federal Coordinator for Meteorology
OGP	Office of Global Programs (NOAA)
OMB	Office of Management and Budget
OMEGA	Operational Medicine Environmental Grid Application (DOD)
OMPS	Ozone Mapping and Profiler Suite
ONR	Office of Naval Research
OOR	Object Oriented Redesign

OPAREA	Fleet Operational Area (DOD)
OPARS	Optimum Path Aircraft Routing System (DOD)
OPC	Operational Processing Centers
OPS-II	Operational Weather Squadron Production System, Phase II
OPUP	Open Principal User Processor
OR&F	Operations, Research, and Facilities (NOAA/NWS)
ORA	Office of Research and Applications (NOAA/NESDIS)
ORAU	Oak Ridge Associated Universities (DOE)
ORD	Operational Requirements Documents (DOD)
ORISE	Oak Ridge Institute for Science and Education (DOE)
ORPG	Open Systems Radar Product Generator (NOAA/OAR)
ORR	Oak Ridge Reservation (DOE)
ORS	Optical Remote Sensing
ORNL	Oak Ridge National Laboratory (DOE)
OROO	Oak Ridge Operations Office (DOE)
OS	Office of Science, South Carolina
OS-21	Observing System 21st Century (DOD)
OSC	On-Scene Commander (DOE)
OSDPD	Office of Satellite Data Processing and Distribution (NOAA/NESDIS)
OSE	Observing System Experiments (WWP)
OSEI	Operational Significant Event Imagery (NOAA/NESDIS)
OSHA	Occupational Safety and Health Administration
OSO	Office of Satellite Operations (NOAA/NESDIS)
OSSE	Observing System Simulation Experiments (WWP)
OSTEP	Ocean Systems Test and Evaluation Program (NOAA/NOS)
OSTP	Office of Science and Technology Policy
OTC	Operational Test Centers
OTH	Over the horizon (NOAA/OAR)
OTSR	Optimum Track Ship Routing (DOD)
OWF	Operational Weather Flight (DOD)
OWS	Operational Weather Squadron (DOD)
OWSE	Operational World Weather Watch Systems Evaluation (WWP)
PAA	Precipitation Accumulation Algorithm (DOI)
PAC	Procurement, Acquisition, and Construction (NOAA/NWS)
PACS	Polar Acquisition and Control Subsystem (NOAA/NESDIS)
PAR	Phased Array Radar
PATMOS	Pathfinder Atmosphere (NOAA/NESDIS)
PAWRP	Phased Array Weather Radar Project
PBL	Planetary Boundary Layer (DOE)
PC	Program Council (OFCM)
	Personal Computer (DOE)
PCB	Polychlorinated Biphenyl
PCMDI	Program for Climate Model Diagnosis and Intercomparison (DOE)
PD	Program Director (DOD)
PDD	Presidential Decision Directive
PDT	Product Development Team
PECAD	Production Estimates and Crop Assessment Division (USDA)
PIBAL	Pilot Balloon
PIPS	Polar Ice Prediction System (NOAA/NESDIS)
PIRATA	Pilot Research Moored Array in the Tropical Atlantic (NOAA/OAR)
PIREP	Pilot Report
PMC	Project Management Coordinator (DOE)
PMEL	Pacific Marine Environmental Laboratory (NOAA/ERL)
PNNL	Pacific Northwest National Laboratory (DOE)
PNT	Position, Navigation, and Timing (USCG)
POES	Polar-orbiting Operational Environmental Satellite (NOAA)

POP	Parallel Ocean Program (DOE)
POPS	Primary Oceanographic Prediction System (DOD)
PORTS	Physical Oceanographic Real-Time System (NOAA/NOS)
ppm	Part per Million (DOE)
PSDA	Post-Storm Data Acquisition (OFCM)
PSR	Polarimetric Scanning Radiometer (NOAA/OAR)
PSS	Plant Shift Superintendent
PUP	Principal User Processor
QPF	Quantitative Precipitation Forecast (NOAA/NCEP)
QuikSCAT	Quick Scatterometer
R&A	Research and Analysis
R&D	Research and Development
RAFC	Regional Area Forecast Center (WWP)
RAMS	Regional Atmospheric Modeling System (DOE)
RAMSDIS	RAMM Branch Advanced Meteorological Satellite Demonstration and Interpretation System (NOAA/NESDIS)
RAP	Radiological Assistance Program (DOE)
	Remedial Action Plan (DOE)
RARC	Regional Atmospheric Response Center (DOE)
RASS	Radio Acoustic Sounding System (NOAA/OAR and DOE)
RATS	Radio Automatic Theodolite System (NASA)
RAWS	Remote Automatic Weather Station (USDA/DOI)
RBCN	Regional Basic Climate Network (WWP)
RC	Reserve Component (DOD)
RCC	Regional Climate Center (NOAA/NESDIS)
RCTM	Road Condition and Treatment Module (FHWA)
RDA	Radar Data Acquisition
RDEC	Research Development and Engineering Center (DOD)
RDTE	Research, Development, Test and Evaluation (DOD)
REIP	Reengineered Enterprise Infrastructure Program (DOD)
RF	Radio Frequency
RFETS	Rocky Flats Environmental Technology Site (DOE)
RFOO	Rocky Flats Operations Office (DOE)
RFC	River Forecast Center (NOAA/NWS)
RMTN	Regional Meteorological Telecommunications Network (WWP)
ROC	Radar Operations Center (NOAA/NWS)
RPC	Rapid Prototype Center (NOAA/SEC)
RSA	Range Standardization and Automation (NASA)
RSAC	Transport and Dispersion Code at INEEL (DOE)
RSFWSU	Remote Sensing/Fire Weather Support Unit (DOI)
RSMC	Regional/Specialized Meteorological Centers (WWP)
RSS	Receiving Set Satellite (DOD)
RTH	Regional Telecommunications Hub (WWP)
RUC	Rapid Update Cycle (NOAA/OAR)
RVR	Runway Visual Range (FAA)
RWIS	Road Weather Information System (FHWA)
SAA	Satellite Active Archive
	Snow Accumulation Algorithm (DOI/BLM)
SAFETEA	Safe, Accountable, Flexible, and Efficient Transportation Equity Act of 2003 (FHWA)
SALEX	Saharan Air Layer Experiment
SAMS	Stochastic Analysis, Modeling, and Simulation (DOI)
SAP	Special Access Program
SAR	Synthetic Aperture Radar (NOAA/NESDIS)
SARSAT	Search and Rescue Satellite Aided Tracking

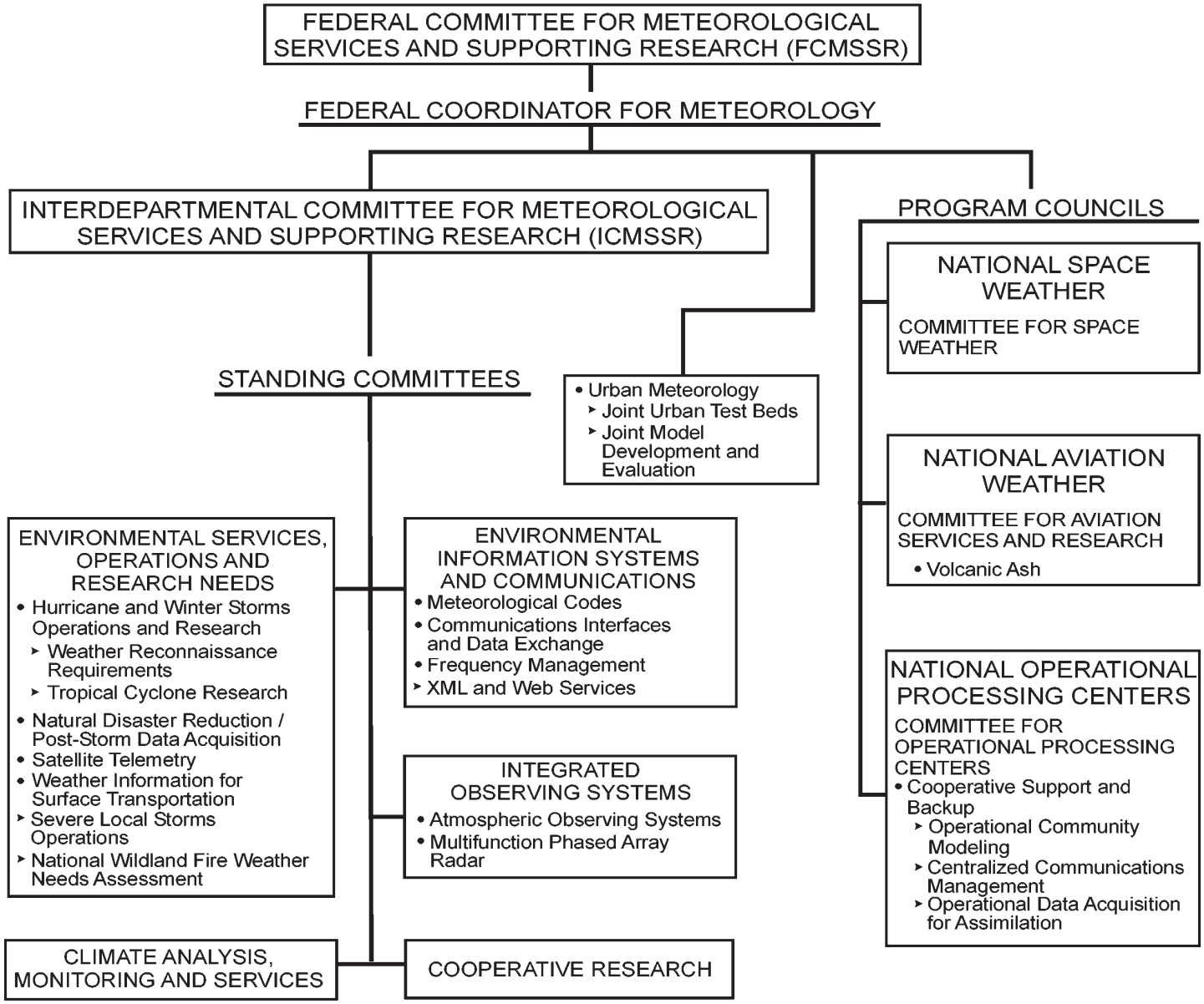
SATCOM	Satellite Communications
SATS	Small Aircraft Transportation System (NASA)
SAWS	Stand Alone Weather Sensor (FAA)
SBIR	Small Business Innovation Research Program
SBUV	Solar Backscatter Ultra-violet Instrument (NOAA/NESDIS)
SCAN	Soil Climate Analysis Network (USDA)
SCAPA	Subcommittee for Consequence Assessment and Protective Actions
SCI	Sensitive Compartmented Information (DOD)
SDHS	Satellite Data Handling System (DOD)
SeaWiFS	Sea-viewing Wide Field Scanner (NASA)
SEC	Space Environment Center (NOAA/NCEP)
	Sun Earth Connection (NASA)
SEM	Space Environment Monitor (NOAA)
SEMSIM	Southeastern Michigan Snow and Ice Management (FHWA)
SEON	Solar Electro-optical Observing Network (DOD)
SESS	Space Environmental Sensor Suite
SFMR	Stepped Frequency Microwave Radiometer
SGP	Southern Great Plains (DOE)
SHEBA	Surface Heat Budget of the Arctic Ocean (DOE)
SHEP	State Highway Emergency Patrol (FHWA)
SHRP	Strategic Highway Research Program (FHWA)
SIGRID	Sea Ice in Gridded Format (NOAA/NESDIS)
SLF	Shuttle Landing Facility
SLRS-C	Spacelift Range System Contract (NASA)
SMC	Space and Missile Systems Center (DOD)
SMDC	Space and Missile Defense Command (DOE)
SMG	Spaceflight Meteorology Group (NASA)
SNDR	Subcommittee on Natural Disaster Reduction
SNL	Sandia National Laboratory (DOE)
SNODEP	SNOw DEPth
SNOTEL	Snow Pack Telemetry (USDA)
SOCC	Satellite Operations Control Center (NOAA/NESDIS)
SODAR	Sound Detection and Ranging (DOE)
SODAR/RASS	Sound Detection and Ranging/Radio Acoustic Sounding System (DOE)
SOF	Special Operations Forces (DOD)
SOLAS	International Convention for Safety of Life at Sea (NOAA/NCEP, DHS/USCG)
SOPA	Synchronous Orbit Plasma Analyzer (DOE)
SORD	Special Operations and Research Division (NOAA/ARL)
SPLASH	Hydrologic Code at LANL (DOE)
SPAWARSYSCOM	Space and Naval Warfare Systems Command
SPC	Storm Prediction Center (NOAA/NCEP)
SPO	System Program Office (DOD)
SPP	Shared Processing Program
SR	Savannah River (DOE)
SRB	Solid Rocket Booster
SRS	Savannah River Site (DOE)
SRTC	Savannah River Technology Center (DOE)
SS&WSF	Snow Survey & Water Supply Forecasting (USDA)
SSIES	Special Sensor for Ions and Electrons (DOD)
SSJ	Special Sensor Precipitating Elecron and Ion Spectrometer (DOD)
SSM	Special Sensor Magnetometer (DOD)
SSM/I	Special Sensor Microwave/Imager (DOC, DOD, DOI)
SSM/T	Special Sensor Microwave/Temperature (DOD)
SSOB	Special Support Operations Branch (DOD)
SST	Sea Surface Temperature
SSU	Stratospheric Sounding Unit (NOAA)
SSUSI	Special Sensor Ultraviolet Spectrographic Imager (DOD)

STAR	Weather Data Format used at Pantex (DOE)
STIWG	Satellite Telemetry Interagency Working Group (OFCM)
STP	Solar-Terrestrial Physics
STS	Special Tactics Squadron (DOD)
STWDSR	Surface Transportation Weather Decision Support Requirements (FHWA)
SURFRAD	Surface Radiation Budget Station at NTS (DOE)
SVS	Synthetic Vision System (NASA)
SWA	Southwest Asia (DOD)
SWAFS	Space Weather Analysis and Forecasting System (DOD)
SWE	Snow Water Equivalent (DOI/BUREC)
SWO	Staff Weather Officer (DOD)
	Space Weather Operations (NOAA/OAR)
SWR	Supplemental Weather Radar (DOD)
SWSI	Surface Water Supply Index (USDA)
SXI	Solar X-Ray Imager (DOD)
T2	Technology transfer
TAF	Terminal Aerodrome Forecast
TAL	Transatlantic Abort Landing (NASA)
TAMDAR	Troposphere Airborne Meteorological Data Reports (WWP)
TAO	Tropical Atmosphere Ocean
TAWS	Target Acquisition Weather Software (DOD)
TCP	Transformation Campaign Plan (DOD)
TDA	Tactical Decision Aid (DOD)
TDWR	Terminal Doppler Weather Radar (FAA)
TEA-21	Transportation Equity Act for the 21st Century (FHWA)
TEC	Topographic Engineering Center (DOD)
	Total Electron Content (DOE)
TED	Total Energy Detector (NOAA/NESDIS)
TEDS	Tactical Environmental Data Server (DOD)
TESS	Tactical Environmental Support System (DOD)
THORPEX	The Observing System Research and Predictability Experiment (WWP)
TIMEX	Thunderstorm Initiation Mobile Experiment (NOAA/OAR)
TIROS	Television Infrared Observation Satellite (NOAA/NESDIS)
TOC	Tactical Operations Center (DOD)
TOE	Table of Organization and Equipment (DOD)
TOGA	Tropical Ocean and Global Atmosphere
TOVS	TIROS-N Operational Vertical Sounder (NOAA/NESDIS)
TNT	Trinitrotoluene (DOE)
TPAWS	Turbulence Prediction and Warning System
TPC	Tropical Prediction Center (NOAA/NCEP)
TPW	Total Precipitable Water (NOAA/NESDIS)
TRACON	Terminal Radar Approach Control (FAA)
TRADOC	Training and Doctrine Command (DOD)
TRB	Transportation Research Board (FHWA)
TRITON	Triangle Trans-Ocean buoy Network (NOAA/OAR)
TRMM	Tropical Rainfall Measuring Mission (NASA)
TRU	Transuric (DOE)
TSIS	Total Solar Irradiance Sensor
TUAN	Tactical Unmanned Aerial Vehicle (DOD)
TWC	The Weather Channel
TWIP	Terminal Weather Information for Pilots (FAA)
TWP	Tropical Western Pacific (DOE)
TWR	Tactical Weather Radar (DOD)
UAV	Unmanned Aerial Vehicle (DOD)
UC	University of Chicago or California
UCAN	Unified Climate Access Network (USDA)

UCAR	University Corporation for Atmospheric Research
UHF	Ultra High Frequency
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization (WWP)
UNLV	University of Nevada at Las Vegas (DOE)
UPOS	University Partnering for Operational Support (DOD)
USA	U.S. Army
USACE	U.S. Army Corps of Engineers
USAES	U.S. Army Engineer School
USAF	U.S. Air Force
USAFE	U.S. Air Forces in Europe
USAFAS	U.S. Army Field Artillery School
USAIC&FH	U.S. Army Intelligence Center and Fort Huachuca
USAR	U.S. Army Reserve
USARAK	U.S. Army Alaska
USARC	U.S. Army Reserve Command
USAREUR	U.S. Army Europe
USARHAW	U.S. Army Hawaii
USARIEM	U.S. Army Research Institute of Environmental Medicine
USARJ	U.S. Army Japan
USARPAC	U.S. Army Pacific
USASMDC	U.S. Army Space and Missile Defense Command
USASOC	U.S. Army Special Operations Command
USCENTCOM	U.S. Central Command
USCG	U.S. Coast Guard
USDA	U.S. Department of Agriculture
USGCRP	U.S. Global Change Research Program
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
USHCN	U.S. Historical Climatology Network
USIABP	U.S. Interagency Arctic Buoy Program (NOAA/NESDIS)
USMC	U.S. Marine Corps
USMCC	U.S. SARSAT Mission Control Center (NOAA/NESDIS)
USN	U.S. Navy
USSOCOM	U.S. Special Operations Command (DOD)
USWRP	U.S. Weather Research Program
UT	University of Tennessee
UTC	Universal Time Coordinated (Zulu)
UV	Ultra-violet
VA	Volcanic Ash
VAAC	Volcanic Ash Advisory Center (NOAA/NESDIS)
VAS	VISSR Atmospheric Sounder
VCP	Voluntary Cooperation Program (WWP)
VII	Vehicle Infrastructure Integration (FHWA)
VIIRS	Visible/Infrared Imager/Radiometer Suite
VIN	Vegetative Index Number (USDA)
VIRS	Visible and Infrared Scanner (NASA)
VISSR	Visible and Infrared Spin Scan Radiometer
VOC	Volatile organic compound
VISTAS	Visibility Improvement State and Tribal Association of the Southeast (DOI)
VORTEX	Verification of the Origins of Rotation in Tornadoes Experiment (NOAA/OAR)
VOS	Voluntary Observing Ship (WWP)
VPR	Vertical Profile of Reflectivity (DOI)
VSAT	Very Small Aperture Terminal (DOD)

VSL	Variable Speed Limit (FHWA)
VTMX	Vertical Transport and Mixing Experiment (DOE)
VTS	Vessel Traffic System (NOAA/NOS)
WAAS	Wide Area Augmentation System (FAA)
WAFC	World Area Forecast Center (WWP)
WAFS	World Area Forecast System (WWP)
WAMIS	World Agrometeorological Information Service (USDA)
WAOB	World Agricultural Outlook Board (USDA)
WARP	Weather and Radar Processor (FAA)
WaRSMP	Watershed and River System Management Program (DOI)
WCT	Wind Chill Temperature (OFCM)
WDA	Weather Data Analysis (DOD)
WEFAX	Weather Facsimile (WWP)
WETM	Weather Team (DOD)
WFAS	Wildland Fire Assessment System (DOI)
WFMIS	Wildland Fire Management Information Site (DOI)
WFO	Weather Forecast Office (NOAA/NWS)
WG	Working Group
WG/VA	Working Group for Volcanic Ash (DOI)
WG/PSDA	Working Group for Post-Storm Data Acquisition (FEMA)
WGCV	Working Group on Calibration and Validation (NOAA/NESDIS)
WINCOM	Weather Information Communications (NASA)
WIMS	Weather Information Management System (USDA)
WINDS	Weather Information and Display System (DOE)
WIPP	Waste Isolation Pilot Plant (DOE)
WIS	WMO Information System(WWP)
WIST	Weather Information for Surface Transportation
WMC	World Meteorological Center(s) (WWP)
WMO	World Meteorological Organization
WMSCR	Weather Message Switching Center-Replacement (FAA)
WOCE	World Ocean Circulation Experiment
WPDN	Wind Profile Demonstration Network (NOAA)
WPSM	Warfighter Physiological Status Monitoring (DOD)
WRD	Water Resources Division (DOI/USGS)
WRF	Weather Research and Forecast (DOC, DOD)
WRS	Weather Reconnaissance Squadron (DOD)
WRTC	Weather Readiness Training Center (DOD)
WSDDM	Weather Support to Deicing Decision Making (FAA)
WSP	Weather Systems Processor (FAA)
WSR-88D	Weather Surveillance Radar-1988 Doppler (NEXRAD)
WSRC	Westinghouse Savannah River Company (DOE)
WSSRAP	Weldon Springs Site Remedial Action Project (DOE)
WST	Weather Specialty Team (DOD)
WWCB	Weekly Weather and Crop Bulletin (USDA)
WWP	World Weather Program
WWW	World Weather Watch (WMO)
	World Wide Web
XOW	Air Force Director of Weather (DOD)
YMP	Yucca Mountain Project (DOE)

FEDERAL METEOROLOGICAL COORDINATING INFRASTRUCTURE



September 2006

LEGEND:
- • Designates a Working Group
- ‣ Designates a Joint Action Group